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Stage Lighting in the Post-war Theatre in Great Britain

By L. G. APPLEBEE *(Fellow)*

Summary

The paper endeavours to give a clear picture of the requirements of stage lighting and indicates some of the difficulties which are met and which have to be overcome. Indications are given of the various uses to which the many different types of apparatus are put. The paper also deals with the very elaborate control that is necessitated by the demands of those who have to use the apparatus and devise the picture that has to be presented to the audience. The subject of colour obtained by the use of light is also discussed. One of the outstanding features of post-war stage lighting equipment is the application of the electronic valve to control apparatus and this type of stage lighting control is described.

Stage Lighting as an Art

Stage lighting always carries an atmosphere of something deeply mysterious or magic. It aims to create stage illusion. Some people have called it an art, but it is the use of the stage lighting which constitutes the art. The man who has to exercise that art is the theatrical producer, the man whose job it is to weld the production into a whole. Given the scenery, the script, the actors, and some lighting apparatus, it is his job to assemble all into what the author intended to convey to the audience when he wrote the play. His problem is a great one, as he must consider the way the actor speaks and moves, the way the set is designed and the clothes are worn, the placing of the "properties" (which are such things as furniture and other impedimenta), and the arrangement of the lighting.

To some extent he will be guided by the script, which will, or should, indicate the hour, the season, and the weather, and therefore in his lighting he must consider these things. Although the design of the scene may have taken some of these points into consideration, in the main their portrayal will spring from the lighting.

In addition, he will, in all probability, be dealing with a scene that is just a flat piece of painted canvas, which his lighting has to endow (to the audience's eye) with the illusion of reality. It must appear three-dimensional, or what is sometimes called plastic or stereoscopic. In arriving at this result he must take into consideration the illumination of the actor, rendering him clearly visible to the audience. Adolph Appia (the Continental producer and disciple of Wagner) said that "light was not only for visibility, but also to obtain realism." Appia particularly laid emphasis on the advantage of stereoscopic effect by means of directional light, its aid in obtaining the light and shade that the sculptor obtains from a carved figure, and he maintained that darknesss and shade are co-partners with light in presenting a scene.

It is easy to overlight; a brilliant all-over intensity or glare that renders the scene "flat" in appearance is inartistic. Not only must the actor be visible, but his features must be given "plastic" expression. This is obtained by the judicious use of directional light: so, in a like manner, with curtains and stage properties. It will therefore be seen that directional light is employed in preference to a widely dispersed general illumination. It must also be remembered that a slight change

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Fig. 1. An example of localised directional lighting for a composite set. ("The Glass Menagerie," Haymarket Theatre, London.)

of the direction of the light that strikes an object or actor can entirely change the "expression." This makes the lighting dramatic.

Let us now see how directional light obtains this three-dimensional or stereoscopic effect, particularly with the actor. Let us start with the acting area, i.e., that part of the stage whereon the actor stands. The acting area must be illuminated quite separately from the other portions of the stage, such as the scenery. To do this the stage is divided into areas and each area is illuminated diagonally by directional light from the front and side as well as overhead. In no case is the light directed flat at the actor's face, but always from an angle of not less than 45 degs.

The areas are completely covered by the cones of light so as to form a complete curtain over the whole acting area and in no case should any of this directed light spill on to the scenery. Plasticity of any parts of the area is obtained by being able to vary the intensity of the "cones" of light impinging on each area. In this manner the point sources of light and restricted beam angles ensure that the shadows found in the wrinkles of an actor's face, or the pleats and folds in a costume, are rendered hard, and thus ensure a sharp definition which will enable even back-seat spectators to register form and shape. The producer builds up any required part of the area, thus unconsciously focusing the attention of the audience to the part so emphasised (Fig. 1).

Now consider the question of scenery. In straight plays nine scenes out of ten are interiors. In the good-class professional theatre, where the interior set is normally fitted with a ceiling, the directional light of necessity comes from (a) the front-of-house, (b) the apparatus fitted just over the proscenium arch on its upstage side, and (c) from the side of the stage. The directional light is soft-edged and is used not only to illuminate the acting area, but also the walls, furniture, etc., of the room, in accordance with what the Americans call "motivating sources" (Fig. 2).

Motivating light is the ostensible reason for there being any light on the stage at all: it may be moonlight, sunlight, the light from a fire or from a chandelier, or even from a candle stuck in the neck of a bottle. Motivating light has to be keyed in with that of the acting area: for example, a burst of sunlight through an open window is adequate reason for increasing the intensity of acting area lighting on one side of the room above that on the other. Again, if a day-lit window is back stage (Fig. 3), an actor facing the audience should not be obviously illuminated by a very strong light from the front, but must *appear* to be lit from the window, yet his features must be visible. It is such a situation that calls for an additional line of directional lighting units throwing cones of light down stage to hit the actor from the back. A similar device is also used in many exterior scenes to render the actor stereoscopic and make him "stand away" from his background.

Types of Stage Lighting Equipment

Some indication of the elaborate arrangements for emphasising various points where light is required can be gauged from these figures: "The Death of a Salesman" at the Phoenix Theatre, employed approximately one hundred and fifty directional units controlled by one hundred and thirty-two dimmer ways, while "A Streetcar Named Desire" used one hundred and sixty-eight directional units controlled by one hundred and seventeen dimmers (Fig. 4).

A lighting unit which is regarded as almost traditional is the so-called "batten." In big London productions at those houses that stage spectacular revues, musical shows, or variety, battens are rapidly becoming secondary to directional units. With the exception of the No. 1 (down stage) and back battens (up stage) they are almost superseded by lighting units that direct the light down on to the acting area in a narrow cone.

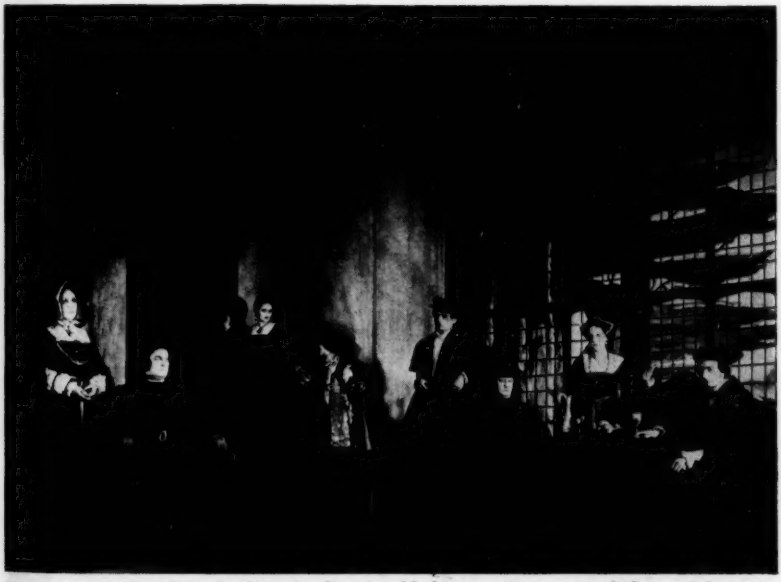


Fig. 2. An excellent example of interior directional lighting against exterior lighting of the backcloth and demonstrating concentration of light on the acting area leaving the top of the scene in comparative shadow. ("Traitor's Gate.")

In the provinces and suburban theatres, battens would appear to have more application for visiting shows, and, of course, the traditional Christmas pantomime, where the large number of drop cloths can, with battens, be given an even distribution of light. Battens, if properly designed, are fitted with reflectors to throw the light down to the bottom of the cloth, so that as far as possible the intensity is the same, both at the top and the bottom. They also, of course, add light to the acting area.

In many cases the "cloth" may be a drapery and the effect of the multiplicity of light sources of a magazine batten will add excitement and interest to the folds of the material, large scale sources giving large shadows and small scale sources giving small shadows. Both are welcome in the theatre.

The footlight is, and has been for many years, a bone of contention. Appia once described it as a monstrosity, for before he developed his theory of directional light, the method employed consisted mainly of flooding the stage indiscriminately, chiefly from the footlight. Nowadays, in the big musicals and revues, the intensity of the downward lighting of the acting area is so high that the footlight just serves to help eliminate the heavy shadows under the actor's chin, nostrils and eyebrows.

In the house that deals with the straight play, the use of footlights is universal. They must, however, be used with care, the circuits being dimmer controlled, the intensity being checked so that just sufficient light is used to balance artistically the overhead lighting. The reflectors are moderately directional with a beam angle of 120 deg. They are designed to project the light vertically to the top of the curtain or front drop. The footlight should be approximately 6 ft. less in width than the proscenium opening, whilst the light source must be above the stage level to prevent a rising shadow to the back of the stage. The housing should not project more than

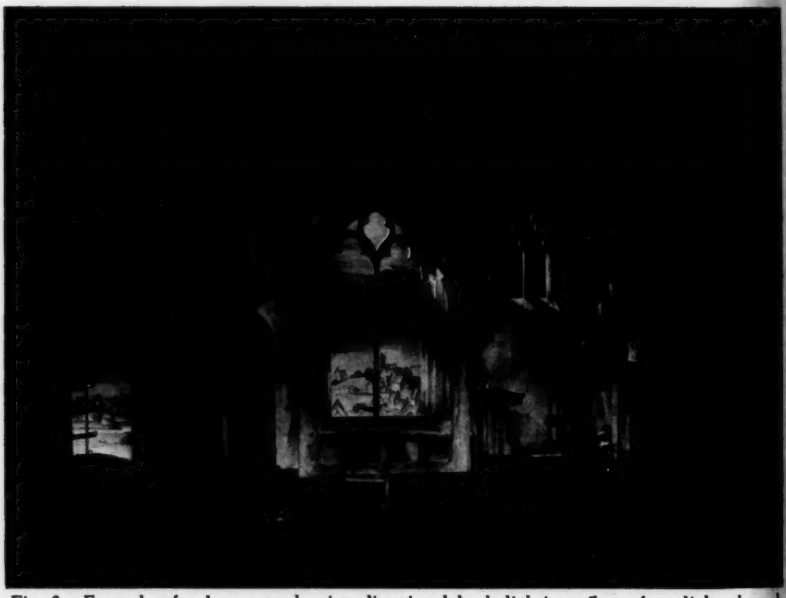
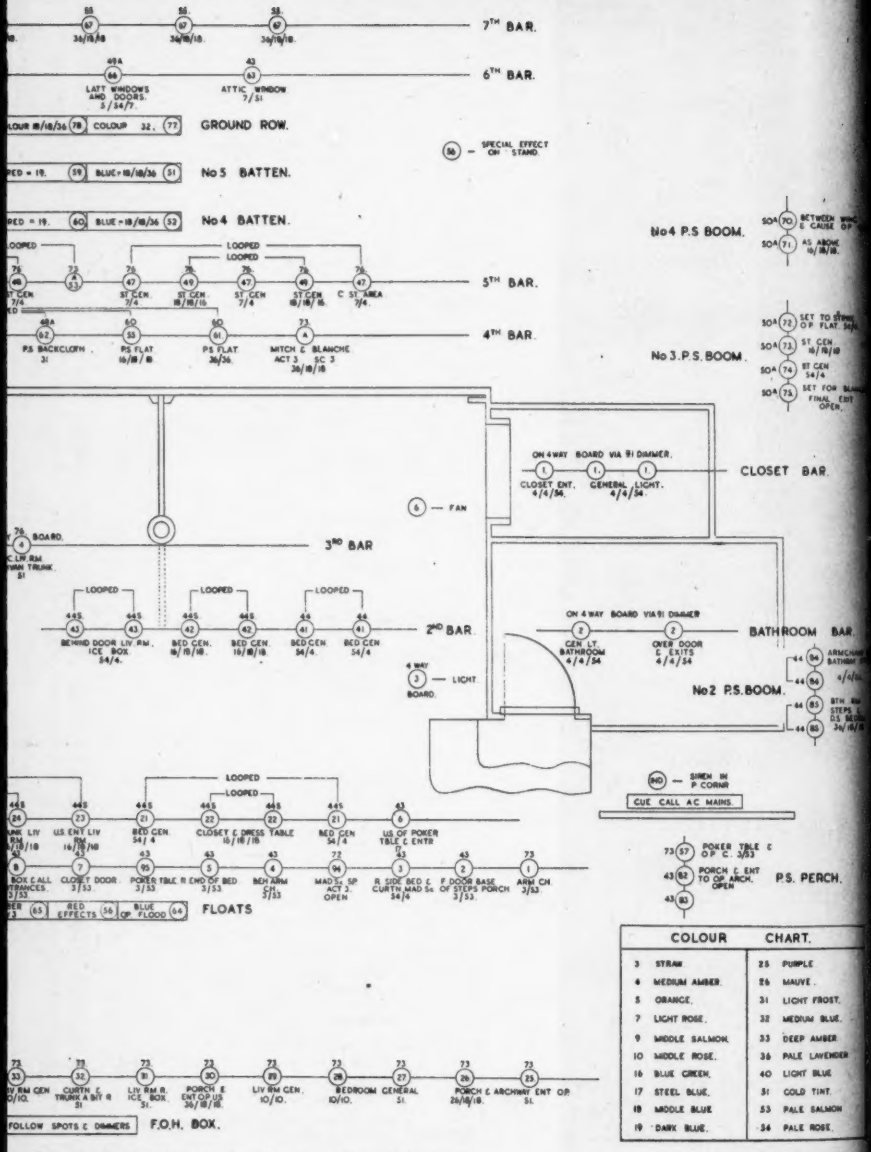


Fig. 3. Example of a large set showing directional back lighting effect of sunlight through windows. ("The Lady's Not for Burning," Globe Theatre, London.)



COLOUR	CHART.		
3	STRAW.	25	PURPLE.
4	MEDIUM AMBER.	26	MAUVE.
5	ORANGE.	31	LIGHT FROST.
7	LIGHT ROSE.	32	MEDIUM BLUE.
9	MIDDLE SALMON.	33	DEEP AMBER.
10	MIDDLE ROSE.	36	PALE LAVENDER
16	BLUE GREEN.	40	LIGHT BLUE
17	STEEL BLUE.	51	GOLD TINT.
18	MIDDLE BLUE	53	PALE SALMON
19	DARK BLUE.	54	PALE ROSE.

London, for the production " A Streetcar Named Desire."

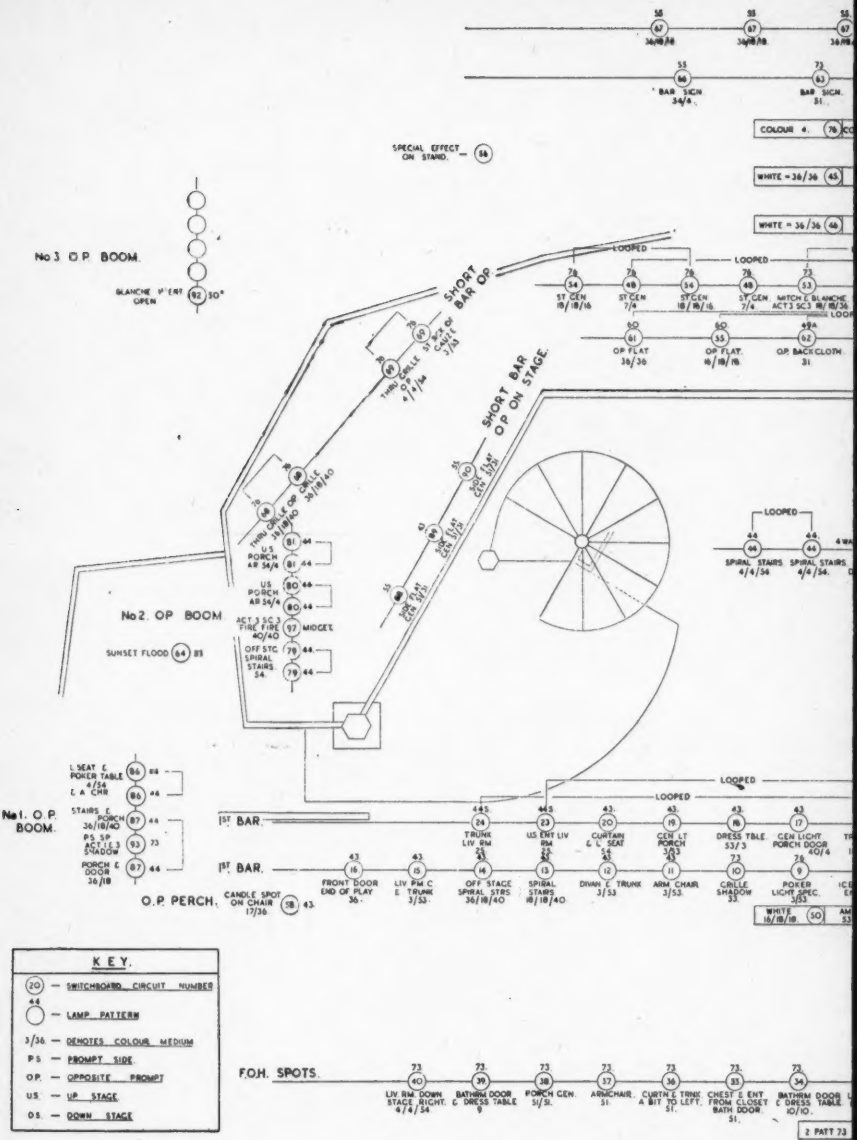


Fig. 4. General lighting layout at the Aldwych Theatre, L

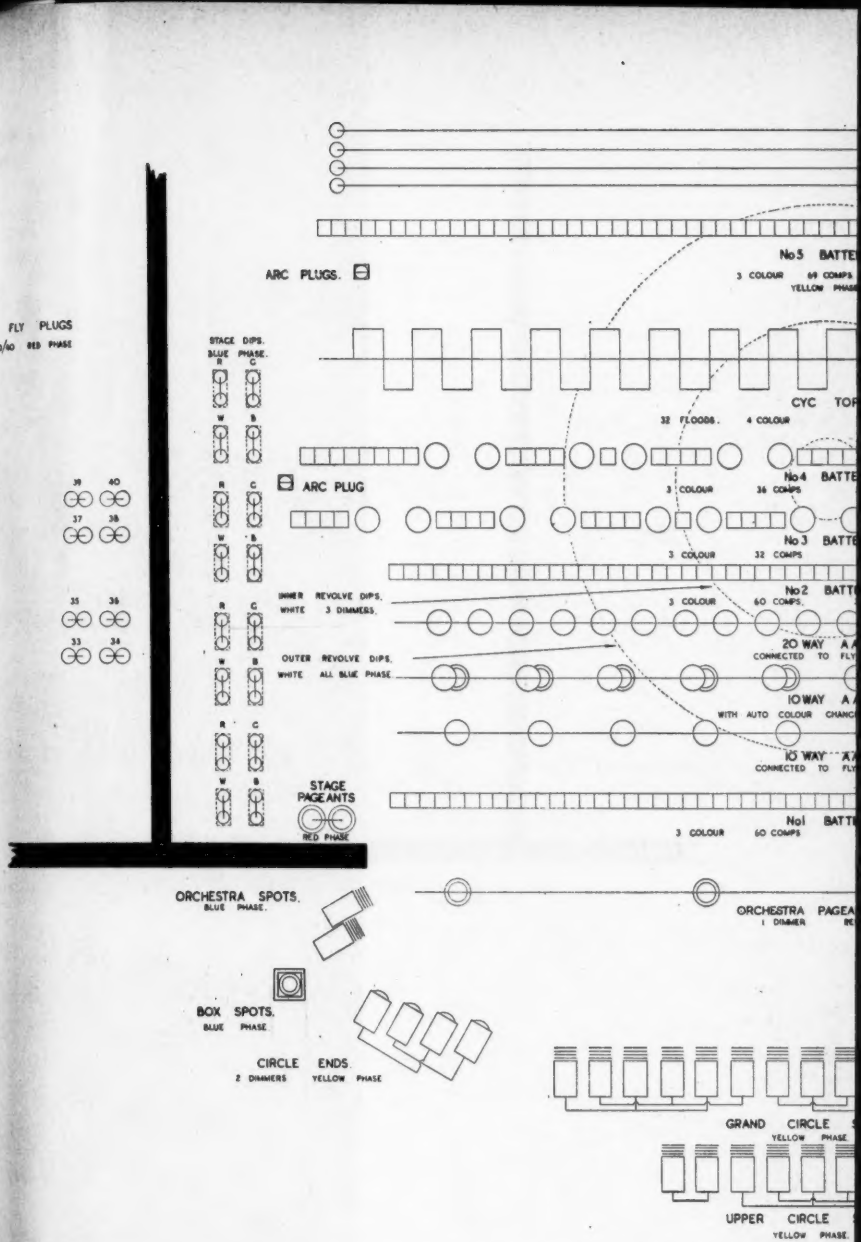
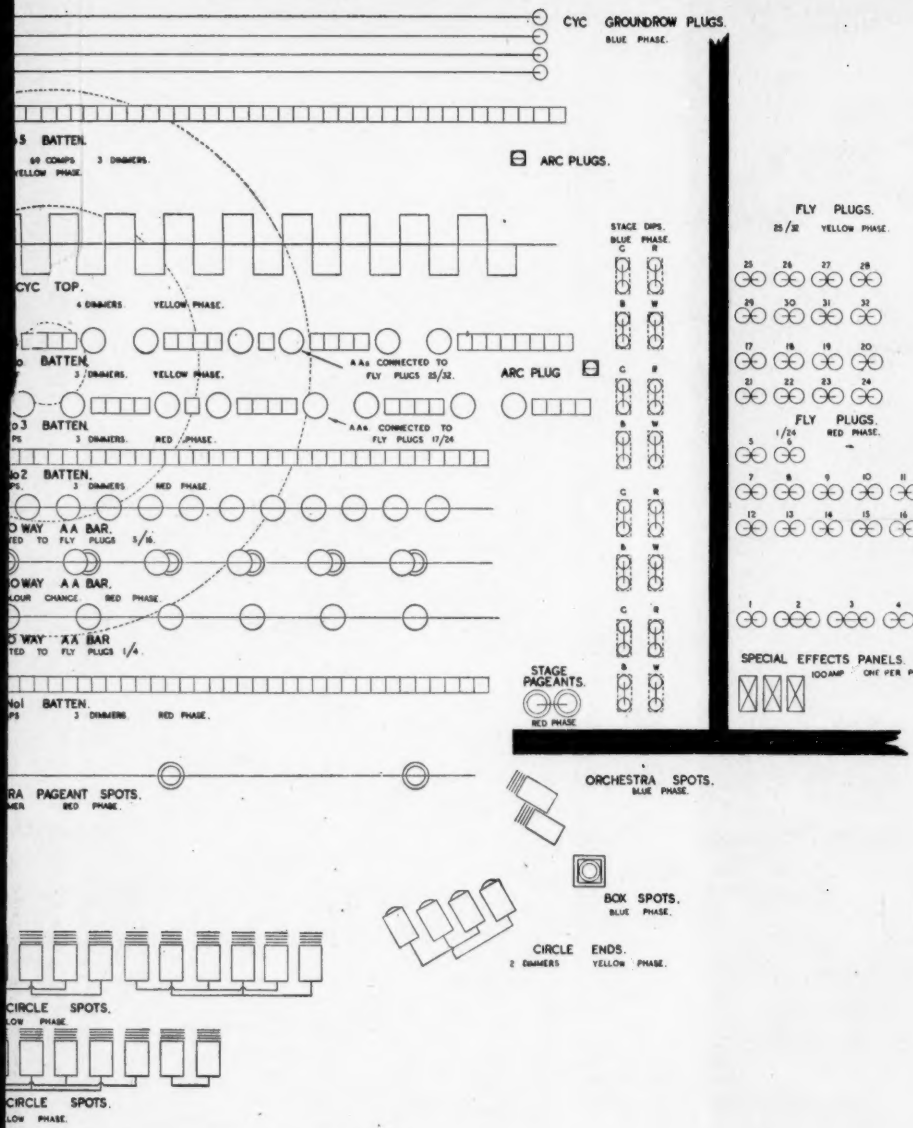


Fig. 5. Diagrammatic layout of stage lighti

ge lighting eq



ge lighting equipment at the London Palladium.

XUM

3-4 in. above the stage level; otherwise, the sight line of the audience in the front stalls will be greatly impaired.

In some of the spectacle types of theatres, additional lighting has been fitted in the auditorium to give cross beams of light catching the side of the actor's face, and footlights have been dispensed with. Examples include London Palladium and the London Casino, which deal exclusively with spectacle.

The lighting of the acting area (see Fig. 5) is by directional lighting units situated in several positions such as :—

(a) On the circle fronts in the auditorium—usually on the second circle, although in a few theatres there are some on the lower circle. They are usually spotlights fitted with 1,000-watt Class A.1. tubular projector-type lamps and spherical silvered glass or anodised-aluminium reflectors. They concentrate the light on a variable gate that can be adjusted so that the shape and size of the beam can be determined to cover any particular object or area without spill. Having passed through the gate, the beam is then passed through an optical lens, which may be a 6-in. × 9-in plano-convex lens, or a Fresnel stepped lens. The beam angle is generally about 19 deg. In many installations these spotlights are fitted with magnetically operated remote-controlled apparatus to change colour screens. The numbers used vary from six to as many as thirty, according to the size of the theatre.

(b) On the spot batten, which is situated just behind the proscenium opening, spotlights are of the soft-edge plano-convex type, usually with 1,000-watt Class B.1. spherical projector lamps. The number varies from eight to sixteen, according to the size of the theatre.

(c) Over the stage are vertical acting area lanterns, usually hung in rows up amongst the sky borders in positions to suit the design of the scene. They are directional flood lanterns in which the cut-off coincides with the beam angle. Reflectors are employed with Class B.1. projector lamps burning cap down. Their function is to throw a cone of light (20 deg. or 40 deg.) vertically down on to the acting area. The number varies : at the Coliseum there are over one hundred and at the London Palladium seventy-five. In some cases where there is a fore-stage a line of these lanterns is suspended from the ceiling in the auditorium to light the stage apron.

(d) At the side of the stage are fitted " boomerangs " consisting of vertical pipe barrels situated in the wings on which spotlights of either the soft-edge or the mirror-spot types as used on the circle fronts are fitted to give the side lighting to the acting area.

Let us now consider some details of the lighting apparatus. It must be of robust construction for rough transport and handling, and the chance of damage through collision with scenery which occurs more frequently than is realised. The London County Council's regulations stipulate that the gauge of metal must not be less than No. 20. Ample ventilation and dissipation of heat is another point that comes within the demands from licensing authorities.

Efficiency of the lighting units and maximum lumen output is, of course, the aim of all designers of lighting apparatus and therefore the fullest use is made of the most efficient light sources suitable together with scientifically designed reflectors. In the main the light sources are gasfilled electric lamps either of the general service or the projector types. The long life and the wide angular tolerance (vertical to 45 deg.) of the Class B.1. round-bulb projector lamp makes its use almost universal in spotlights and directional floodlights, although where the lamp in the lantern can be kept within the permissible angle the A.1. type is used. In this country lamp manufacturers have not standardised an essential dimension on the various types. It would be a very great asset if in all types of projector lamps of the same rating the dimensions from the base of the cap to the centre of the filament were standardised.

A big step forward was the introduction of the pre-focus cap to projector lamps.

XUM

This, together with standard dimensions from cap to filament centre, will do much to improve spotlight efficiency.

The gas-filled projector lamp has, generally speaking, deprived the electric arc of its former prominent place. To-day the latter is only used for "following" spots, usually situated at the back of the topmost circle and normally used for following star performers (Fig. 6). Here there has been a distinct advance in technique. The increase in the intensity of light in the acting area necessitates a very high lumen output from these lanterns, as to be of any value their circle of projected effect must produce an area of light of intensity well above that of the general stage lighting. To-day, therefore, the high-intensity "mirror" arc, similar to the apparatus used for the projection of films, is employed. The current consumption varies from 60 to 100 amps, and the lanterns are fitted with many accessories such as manually operated shutters that can vary the shape of the beam, both vertically and horizontally, an iris diaphragm to alter the spot size, and a magazine of colour filters. They normally operate on a D.C. supply (50 volts across the arc) from either a motor generator or rectifier, but the introduction of the A.C. arc has led to the use of inductors with an input of 15 amps and an output of 90 to 100 amps (25-28 volts across the arc).

Fig. 6. A following spot used in musicals, revues, etc. Commonly called "limes."

Various materials, such as stainless steel, chromium plate, silvered glass, and anodised aluminium, have been tried for reflectors. For many years these have been plain spherical in shape for spotlights, and of broken surface for floodlighting units, battens, and footlights.

The size of the Class B.1. projector type lamp envelope prevents the use of the ellipsoidal reflectors in spotlights as the size of the lantern must be limited. Spotlights on the stage are mostly used in positions where space is limited, and units must be kept as small as possible, particularly for hanging amongst scenery. The spot batten, usually as near the proscenium as possible, competes for space with tableau curtains, act drops, advertisement curtains, proscenium borders, etc., and the spots must be as small as the heat output of the lamp will allow, even if some loss of efficiency results. Reflectors and lenses larger than 6 inches diameter would not be popular. Anodised aluminium is heat-resisting, robust and non-tarnishing, advantages which cannot be ignored. The slight etching of the metal to give a matt finish is also useful in reducing the filament image that occurs with the glass spherical reflector, particularly where a narrow beam angle is used.

Ellipsoidal reflectors both of glass and anodised aluminium are being introduced for floodlighting units such as wing floods, acting area lanterns, battens, and footlights.

A most important part of the lighting apparatus is the medium used to obtain colour. It is unfortunate that glass manufacturers are only able to produce a limited colour range, such as signal green, ruby red, a blue that is almost a purple, a thin amber, and a very washed-out pink. These are practically useless. Stage-lighting technicians are, therefore, forced to use other materials which must be non-inflammable. Those available are of limited durability and colour stability. The cheapest and

most popular substance is gelatine, which, however, has a very limited life, as after a period of a few weeks it begins to fade and crack. Another substance is a plastic material which has more resistance to fading, does not crinkle, is impervious to water, and is non-inflammable. In both these materials there is a range of over 40 colour hues. It is very seldom that bare lamps are used on the stage. Colour mediums, even though of pastel shades, are almost universally used.

Use of additive colour-mixing for any portion of the stage lighting other than the cyclorama is not satisfactory. Colour is obtained by using various selected filters in individual units. Colours are chosen by the producer himself. For the straight play it will be found that he prefers the pastel shades, chosen on the basis of the time of day, the motivating light, and by the dominant colours in costumes, hangings, and furnishings.

In theatre work, colour filters are seldom required to pass a narrow band. For most purposes filters suppressing a part only of the spectrum are more commonly used. For example, a "straw" filter decreases the amount of blue, while a lavender filter decreases the amount of green and brings blue and red objects into prominence.

The characteristics of the filters are shown by their spectrophotometric absorption curves, which provide a useful means of checking each batch of colour filters and avoiding variations. These curves might be thought to be of use in the theatre itself, but in practice an artistic eye for colour, plus a little experimenting, is a far more valuable guide. The truth is that in the theatre there is not substitute for the artistic sense for pictorial effect.

Coloured light plays a very important part in enhancing costumes. The surface of the materials and the way the dye or pigment is applied will influence the colour. The softer and rougher the surface, the deeper and more dominant will the colour appear.

If the costumes are properly dyed for use under coloured light, then the most inexpensive materials can appear as the richest of fabrics. Coarse hessian is frequently used effectively for tapestries, and cheap sateen assumes the appearance of velvet. A cheap muslin will, in fact, surpass crêpe-de-chine in quality and richness.

The so-called "Black Light" has its place in the theatre for "ghosts," illusions, etc. Manufacturers, both here and in the United States, are weaving materials that themselves fluoresce without the necessity of spraying. "Black Lamps" may sometimes be used simultaneously with normal stage lighting to enhance the brilliant colouring of costumes.

The Cyclorama

Briefly, the cyclorama consists of a screen which is lit to represent the sky. It has to produce to the audience the illusion that one is looking at a *real* sky, and there must be a sensation of depth, of looking out into vast space (Fig. 7). Fortuny's original cyclorama had the shape of a "quarter-orange." The flat back wall of the stage, if properly treated and illuminated, can give an equally good illusion. In some cases a curved type of canvas carried on a circular track is employed, so that, when not in use, the canvas cloth can be wound up and stored at the end of the track travel in the wings. This method is much used on the Continent, but the only four examples in England are the Royal Opera House, Covent Garden, the London Coliseum, the Cambridge University Dramatic Club, and the St. Martin's Theatre. There are, however, restricted portable canvas cycloramas, which are flat with curved ends, built on a wood frame of some type of building board faced with canvas, and flown when not required. That at Stratford-on-Avon is of plaster on a steel framework; by arrangements of wheels on the fly rail it can be moved up or down stage. It weighs 33 tons, but can be moved by one man working an endless chain.

Provided that the stage is at least 24 ft. deep the back wall, treated with cement

Fig. 7. An example of chamber set showing localised and cyclorama lighting, ("September Tide," Aldwych Theatre).

having a slightly roughened surface and distempered white (not an oil-bound paint), has been found satisfactory. Its appearance under white light should be that of white blotting paper. Lighting of the cyclorama must be even. For the top lighting wide-angle floods of not less than 100 deg. beam angle are usually employed, the result being that each lantern projects layer upon layer of light on to the surface over the full width of the cyclorama.

The method of placing the lights is important if the effect of distance is to be obtained. The lighting is in two sections and the top or main lighting section should cover evenly two thirds of the height of the cyclorama, dying away over the bottom third. Therefore, for the flat cyclorama, such as the back wall of the stage, the lighting units should hang at approximately 12 ft. from the surface of the cyclorama, although circumstances often make this dimension less. The bottom or "horizon" lighting section should be fitted quite close to the surface to light about the bottom third up the cyclorama, thus giving the illusion of a distant horizon.

The method of colour lighting varies. On the Continent the Schwabe-Hasait system is employed, using four hues of blue, one of red, one of amber, and one of green. In England, however, the additive system, propounded in 1803 by Young, is employed. Young shewed that by varying the intensity of red, blue and green light various hues of colour could be obtained. However, as red and green are seldom required by themselves for sky effects, it is rather wasteful to tie up lanterns to these colours. Therefore, a deep orange is substituted for the red and a blue-green for the green. The bottom, or horizon, lighting usually retains the orthodox three primaries. It is worth remarking that many productions require only blue sky effects and, consequently, all the lighting units will be blue of one hue or another. With the wide-angle floods, standard stage colour filters are used; and, as the gas-filled

lamp is poor in the blue end of the spectrum, a great number of lighting units will be required on the blue circuit.

As a light source, the fluorescent lamp has a high content in the blue end of the spectrum, and manufacturers of this type of lighting unit have been endeavouring to produce colours that will be as near as possible to the spectral hues required for the cyclorama. At the moment the colours available are pale compared with those normally required on the stage. Thus the tube called deep blue is to us in the theatre a pale blue and requires a deep blue colour filter in addition before it is tolerable as deep blue.

The normal efficiency of the fluorescent lamp both in current consumption and lumen output would be an advantage in lighting a big cyclorama, and much experimental work is being undertaken by a number of manufacturers of lamps and of stage-lighting apparatus.

Installed Loading

The foregoing will have given some idea of the method of lighting employed. The number of units naturally depends on the size of the stage and the type of "show." Allowance is always made for the temporary use of apparatus for a particular play, and therefore numerous plug points are provided to which this apparatus can be connected as and when required. Such circuits are all provided with dimmers.

An indication of the connected loads of some theatres will give an idea of the size of stage lighting installations. Here are the connected loads (stage lighting only and exclusive of D.C. arcs) of some of the English theatres:—

Royal Opera House, Covent Garden	850 kw.
The Opera House, Blackpool	350 kw.
The London Coliseum	656 kw.
The London Palladium	345 kw.
The St. James's Theatre	200 kw.
The Royal Court Theatre, Liverpool	250 kw.

These may appear large, but the loads of some foreign theatres make them appear almost insignificant.

The Metropolitan Opera House, New York	870 kw.
The Roxy Theatre, New York	2,500 kw.
Radio City Musical Hall, New York	3,150 kw.
Red Army Theatre, Moscow	4,150 kw.

Such loads seem phenomenal, but the theatres are themselves unusual. Radio City Musical Hall, for example, seats 6,150 people.

Control

The various lighting circuits on the stage have to be controlled, switched on and off singly or in groups from some central position. More important, the circuits have to include dimmers so that intensities can be regulated and balanced, and so that lighting changes can be gradual or imperceptible. Shutters are seldom used for dimming in British practice except in the manually-operated following-arcs. Reduction in light is effected by reducing the voltage applied to the lamps.

There are four types of dimmers in use to-day: Resistance, auto-transformer, indirect electronic, and direct electronic. The resistance is still the cheapest and simplest dimmer to construct. It takes many forms, two being the liquid type (now obsolete) and the nickel copper resistor, wire-wound on element-type formers from which tappings are brought out to stud contacts to give at least one hundred steps of resistance

The resistance dimmer can only give its intended dimming curve on the load for which it is wound. Dimmers giving a variation of load (e.g., 1,500 w. $\pm$ 500 w.) are

common, but although the dimmer will dim right out in every case the curve is of course displaced. Heat losses are not as serious as might appear at first sight, the maximum loss is 36 per cent. watts at 5 per cent. lumens, falling to 17 per cent. watts at half intensity. Electrical efficiency is not often of great importance since in many shows dimmers are mainly set at "full on."

The tapped auto-transformer dimmer was developed to give a constant dimming curve irrespective of the load connected to it. Unfortunately the auto-transformer, when constructed to comply with regulations in this country, is many times more expensive than the resistor dimmer. In the very few installations using it only some of the stage circuits (important for variable load) have transformers, the remainder having resistors. On the Continent much use is made of transformer units feeding, through a busbar form of commutator, a dozen or more dimmers, thereby spreading the cost.

Earlier forms of electronic dimmer were indirect in operation, the valves being used to pass controllable D.C. into the saturating winding of a choke in series with the lamp load. This system is still common elsewhere, particularly in the U.S.A., where 120-v. supplies give rise to currents of double those which we have to control for the same load. Here we have been able to avoid the expensive complication of a saturable choke and control the lamps directly from the valve.

A three-valve combination, one per phase, is used for each dimmer. The valves are grid-controlled rectifiers, and therefore although the stage supply is three-phase A.C., the lighting itself is fed with D.C. and problems of phase balancing

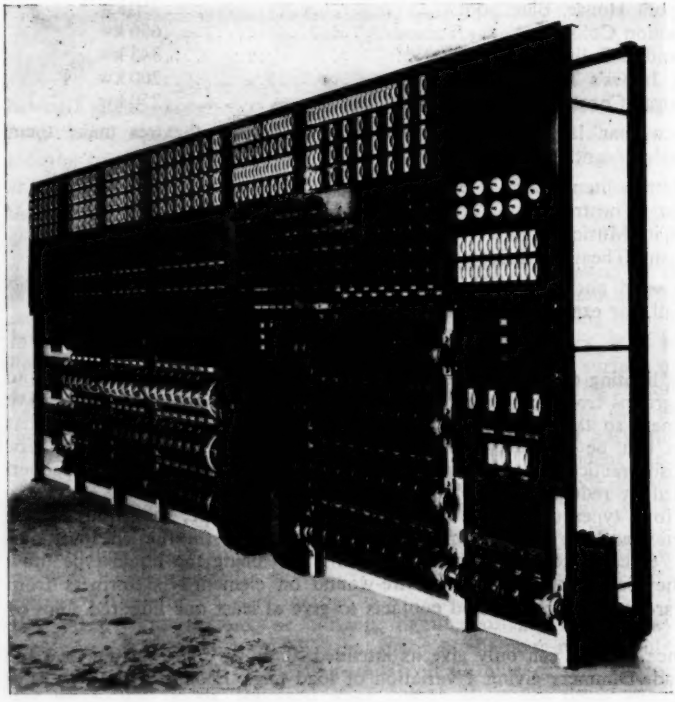
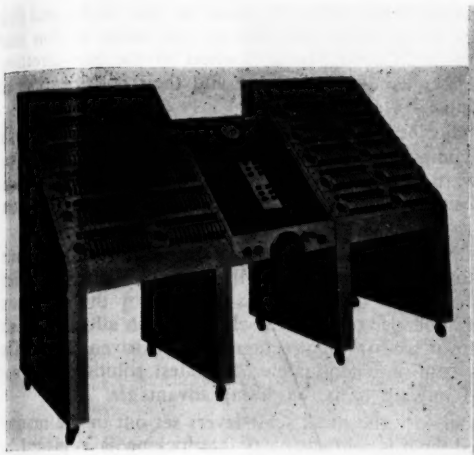


Fig. 8. Manual "Grand Master" control board using wire dimmers (100 ways). (Opera House, Blackpool).



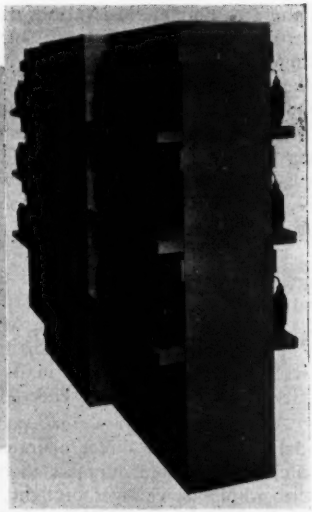


Fig. 9. (Left). The control desk for electronic system of remote control (144 ways) of stage lighting which allows for the pre-setting of dimmer and switch positions before the "cue" or scene and while the previous scene is still in action. (New Theatre London).
Fig. 10. (Right). The valve bank of an electronic control system.

are eliminated. The dimmer control is a small grid potentiometer which can be remotely operated. In the direct electronic dimmer we have a compact unit completely independent of load variation and comparatively reasonable in price. At present each three-valve combination can control up to 2 kw., but several combinations can be operated from the one control potentiometer. The dimmers are silent in operation and give much improved electrical efficiency since the main loss is represented by the small heater current. There remains the question of valve life, and if, as experiment and expert opinion indicate, this is long, then the electronic dimmer will effect as big a revolution in the theatre as did the metal resistance when it replaced the liquid dimmers.

Whatever the form of the dimmers, their control handles require to be assembled for individual and group manipulation. Dimmers are seldom few in number, as the schedule below shows, and arrangements have to be made to lock the handles together for group operation, preferably by one man.

Number of Dimmers Installed in Various Theatres

Drury Lane Theatre	216
Stoll Theatre, London	176
New Theatre, London	144
Palace Theatre, Manchester	108
The Haymarket, London	84
Theatre Royal, Bristol	60

The simplest arrangement is to place the dimmers behind a panel and pivot their operating handles on a shaft or shafts in front. Arrangement can then be made to lock the handles to the shafts for collective operation. Some of these are quite simple, but in the case of the "Grand Master" Cross Control Board (Fig. 8) they become mechanically elaborate. There are several sets of shafts, some allocated to particular colour groups and some to particular families of equipment, such as spotlights and

acting area floods. The various dimmer handles can be locked to their shafts and their shafts in turn locked at will, some to run their dimmers up and some to run their dimmers down, by turning the centre "Grand Master" wheel in the one direction. When the wheel is turned the dimmer handles also move and their positions can be read off on scales fitted to each handle.

A board such as this can usually be handled by one or two operators, but with many dimmers, rapid changes and complicated switching cues are required, and this type of board is apt to become awkward and slow in operation, particularly as its size precludes it being placed in a position where a reasonable view of the acting area can be obtained.

The solution is to operate the dimmer remotely from miniature levers on a compact panel which can then be placed to get a better view of the stage. There have been many systems devised to enable the remote dimmer to be operated by the movement of a miniature lever, such as the Mansell electro-magnetic clutch, which allows dimmers to be connected to travel up or down from a unidirectional motor-driven shaft. The electronic dimmer provides in its control potentiometer the latest solution, and one which, because of the absence of moving parts, has clear advantages.

We can now have a small panel with the small scale levers set out in the manner usual on the large direct operated boards. Mechanical interlocking is replaced by switching to enable dimmers to be grouped on master or grand master faders. To cover wholesale changes of lighting a second panel is provided with a duplicate set of levers; thus one panel can be used to hold the lighting while the other panel is pre-set for the next large change. Then on cue the master fader is operated and the lighting changed over proportionately from one set of lever positions to the other. For 144 dimmers and usual accessories a panel occupies approximately 8 ft. 6 in. wide × 3 ft. 8 in. high overall. (Figs. 9 and 10.)

Consoles

There are certain types of spectacular shows in which the number of dimmers is not only very high indeed, but large numbers of changes follow rapidly. An attempt

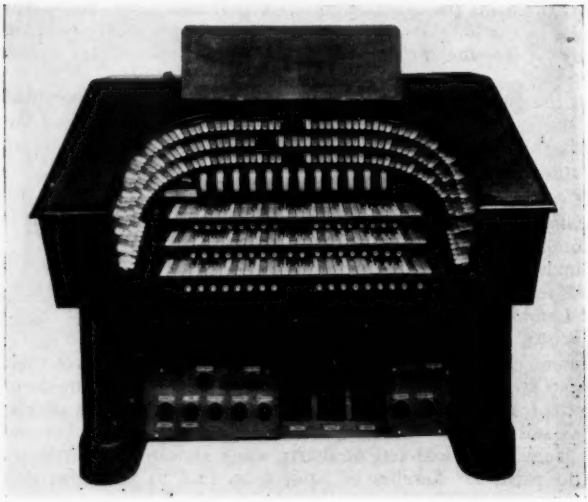


Fig. 11. The control desk of a lighting console (216 ways). (Theatre Royal, Drury Lane).

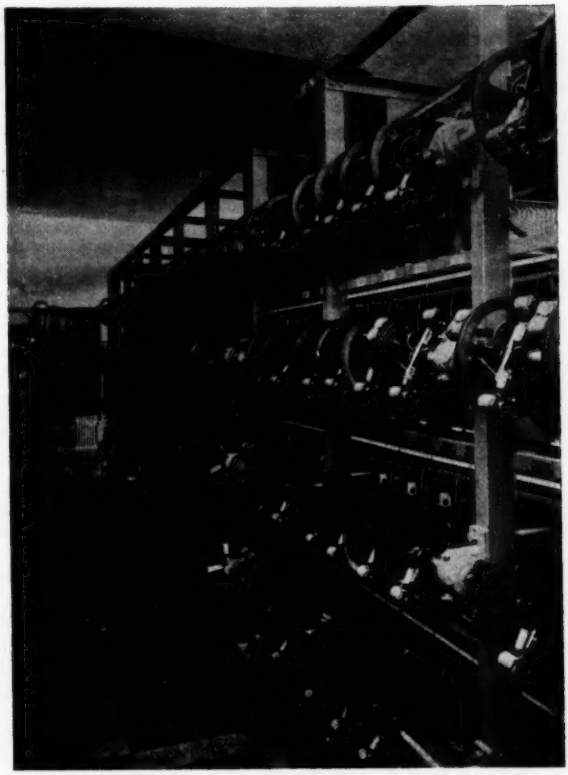


Fig. 12. The magnetically operated dimmer bank controlled from the light console desk.

has been made to solve this in America by adding six to ten pre-sets, which means that for a board of 200 dimmers there are 1,200 to 2,000 dimmer levers.

In England we have yet another solution for this kind of problem—the light console. This does not provide pre-setting of dimmers but aims to place all controls convenient to the hands (and feet) of a seated operator, who can group them rapidly as required. To this end an organ console with stop keys and keyboards is used.

Basically the system differs from others in that the individual dimmer control levers, position scales, circuit switches, locking switches, etc., are replaced by a single switch (stop key) per circuit. This stop key locks its own lighting circuit, and any others whose stop keys are down, to a master keyboard for movement. The master keyboard comprises a few sets of keys for the operations normally represented by the sets of individual levers. Thus, whether one or one hundred dimmers are to be moved, the masters are always used. When a stop key is put off the lighting of that circuit remains where it was last set by the master. The master keyboards, which represent various "families" of lighting instruments, can in their turn be coupled together. Dials indicate at will what movement the masters are applying or the intensity of individual dimmers.

Where lanterns are fitted with remote colour change the same stop keys are used as for their dimmers, the master keys being the five "notes" shown black in Fig. 11.

Again there is saving of space, especially as the number of these lanterns may be large.

The organ-type stop keys lend themselves to rapid operation, a sweep of the hand putting them on or off. In addition, the usual organ combination action giving pre-set movement of the stop keys on or off, is fitted. The way this is arranged is shown by Figs. 11 and 12 of the 216-way console for Drury Lane Theatre.

The meticulous lighting changes for the Old Vic productions at the New Theatre, London, are controlled from a 144-way one-pre-set electronic board in a room with observation window at the back of the pit, whereas the spectacular lighting at the London Palladium is "played" by a girl seated at the light console at the end of the grand circle.

The pre-set board is of wider general application in the theatre and has the further advantage that its desk is less costly than the organ console to construct; it is not beyond possibility that in the future a theatre desiring real versatility of control might have both a pre-set desk and a light console available to operate the same electronic dimmer bank.

Conclusion

What intensity is needed for effective stage illumination? There is no recognised standard of so many footcandles recommended, and the photometer is seldom, if ever, employed on the stage itself. It has its use in comparing the output and distribution of lighting units, but there its useful function ceases. Stage lighting to-day is not a wholesale flooding of light over a given area, it is directional; and a large number of lighting units is employed, each dimmer-controlled so that its intensity can be varied. The result will not be a matter of intensity but of illusion or pictorial effect, to present to the eyes of the audience the picture (with its dramatic emphases) that the author had in his own mind when he wrote the play. The producer is not tied to a scientific measurement of light but rather wields the free hand of a painter of pictures. The illuminating engineer therefore stops at the efficiency of his apparatus. Its use must be purely artistic.

British stage lighting apparatus, is, in the author's opinion, as good as, if not better than, any produced by other countries. It is constantly being revised and re-designed by the manufacturers to produce the most efficient units. Its use and the effects and results obtained are dependent on the technique and artistic sense of the theatrical producer, not the illuminating engineer.

My thanks are due to Mr. Joe Davis, lighting technician to Messrs. H. M. Tennent, for permission to reproduce photographs, and for the details of "A Streetcar Named Desire," and to the Strand Electric and Engineering Company for assistance in preparing the paper.

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Discussion

MR. CHRISTOPHER EDE said that as an actor and producer he spoke from the customer's point of view, or at least from the point of view of the man who used the equipment. Although the theatre was called an industry, he was not at all sure that that was right. It was certainly not a well-organised industry, for producers had to

work in all sorts of different places with all kinds of different equipment. Further, 95 per cent. or more of the labour in the industry was casual labour; actors were for the most part casual labourers and he himself was one.

As regards lighting, he asked the delegates to remember that this was only one of the tools of the theatre and it must be subservient. It is very easy to get excited about lighting, but very dangerous. No bad play had ever been made a good one by lighting, although some good plays had been ruined by bad lighting. Lighting must serve the play and first and foremost the actor must be lit. If an actor had to speak in the dark, the audience invariably said they could not hear. He had checked that with medical authorities and it was a physiological fact. In the dark, so much concentration went into trying to see, that hearing became impaired.

Commenting on the use of directional light, he said that in the production of an opera in London recently, the first thing he did was to get rid of all the battens and footlights, because he did not want light spread all over the scene. He had to do the same production in a few months' time in a tent seating 9,000 people. It was, he believed, the biggest tent in Europe, just over the border in Wales. This was an illustration of the difficulties of the producer's job, and the varying conditions in which he had to work.

He put in a plea for the pre-focus cap, as a great saver in time, for time was always vital in the theatre. The replacement of a lamp at a dress rehearsal meant that the wretched electrician had to cope with a hot lantern, probably at the top of a ladder, while possibly 20 artists were hanging about. Unless the lamp was a pre-focus type the focusing was probably all wrong when he had finished.

Perhaps the most important factor from the point of view of the producer was that his equipment must be flexible, because he wanted light of the right intensity at the right moment and in the right place. The producer was not interested in balance of phases or heat losses, he wanted tremendous flexibility and speed of control. The most important development since the war was the electronic switchboard which enabled dimmers to be pre-set. Complicated changes of lighting which had been very difficult hitherto, had become simple with this control and he looked forward to the time when the electronic switchboard became generally available.

A great deal of theatrical activity was concerned with touring, and while lightness in equipment was important, it had to stand up to a good deal of hard handling in transport.

MR. J. HODGKINSON (Regional Director to the Arts Council for the North-West Counties) said that with equipment getting more and more elaborate, he felt that the stage electrician was becoming the most dangerous man in the theatre because he had so many things under his control. Therefore, it was essential to get back to first principles and ask the question: What was stage lighting for and what was the stage electrician for?

The first task of stage lighting was to enable the audience to see what was going on on the stage. He emphasised that the audience should really be able to see, because some producers thought it sufficient if the audience could only *just* see.

The second task of stage lighting was to give shape to what was taking place on the stage. There was a certain architectural quality to be secured and here the electrician had the job of trying to make things have a stereoscopic relationship to each other.

A third task of stage lighting was to give significance to the art which was being portrayed, and in this stage electricians could become real artists in interpreting, in terms of light and shade, what was taking place. This should be done in such a way that the technique of the thing should not be noticeable or visible at all. Indeed, the

electrician should be annoyed if it were. That was the answer. If the lighting was absolutely right it should not be noticed.

Another and very important aspect of stage lighting was that small halls presented problems of their own and these small stages were not receiving the attention of lighting engineers which they deserved. There was great need for flexibility of equipment. He admitted that spot lanterns and flood lighting and other equipment were very cleverly designed but he still thought that if some of those who designed and manufactured this equipment had to work it in the restricted conditions of small halls, they would realise that there was not yet sufficient flexibility or adaptability. Some of the equipment now available was much too large and he would like to know that somebody was working hard on smaller equipment.

Then there was the problem of heat from the lighting equipment and he asked if it was too much to hope that technical skill would effect a lessening of this. Some stages were like ovens. Perhaps the fluorescent lamp was the answer. There was also the need for a better colour medium and perhaps the fluorescent lamp would answer two problems at the same time. These were very urgent questions.

MR. L. DU GARDE PEACH said that he liked his plays to be both heard and seen: it was the second of these which concerned the present conference. And this applied both to large stages like the Coliseum in London, and his small amateur theatre up in the hills, not far from Buxton.

Two things were desirable in a modern theatre: plenty of spots—i.e., directional lighting, both in front of and behind the proscenium, and that all lighting should be flexible. It should be borne in mind that angled directional lighting created the illusion of depth, even on shallow stages, and front of house and proscenium spots should always be installed in such a way as to cross beams on the stage. The lighting should also be simple to control, and he was appalled at some of the modern remote-control lighting consoles now on the market. The average stage electrician would be more likely to play "Land of Hope and Glory" on them, than to light the stage!

Stage lighting, especially in small theatres, was a matter of importance, as village halls and community centres are going up, or soon would be going up, all over the country. The new enthusiasm for amateur drama, fostered by the local Education Authorities, meant that all these halls would need stages, and the stages must be adequately lit. Good lighting was as easy and as cheap to install as bad lighting, and it was up to the technicians concerned to know the difference—especially as frequently the amateurs did not.

Simple resistance dimmers, without switches, were to be recommended for village halls and small theatres. These dimmers present no difficulty to the amateur stage electrician, and if enough of them were put in—about 24 circuits were adequate—they were sufficient for any stage effects likely to be required.

Finally he asked lighting engineers to try to understand the problems of the producer—just as the producer must always try to understand the problems of the lighting engineer.

MR. E. E. FARADAY emphasised the need for simplicity of equipment for small stages. The amateur theatre of the civic type and the Town Hall had very largely been neglected in that respect and there was a tremendous scope for the manufacturers of lighting equipment to concentrate their efforts on meeting the varying needs of these small halls with their great limitations. This would help them to get very much better results much more easily than had been possible in the past. He also urged lamp makers to push ahead as fast as possible with the development of new sources of light for there were big limitations in the existing sources. Fluorescent lighting gave some

hope but there were tremendous difficulties; and as representing a manufacturer of stage lighting equipment he would say that he believed the manufacturers of such equipment would welcome a lead from the lamp manufacturers. His own view was that hitherto the big theatre had received too much attention and the small theatre should really be the starting point. Therefore, he asked that the attempt should be made to develop standard units suitable for the small theatre and, at the same time, he appealed to those running the small theatres not to ask for all sorts of modifications which only had the effect of putting up the cost.

MR. G. T. KINGSLEY-LARK said that the great technical advance of the electronic dimmer had rather overshadowed the potentialities of the d.c. saturated choke. About five years ago he applied the d.c. saturated choke in combination with a transformer starter (instant start circuit) for the light output control of fluorescent lamps. The details of the circuit were well known and he was indebted to "The Electrical Review" for describing the system about two years ago. Initially the device was limited to auditorium lighting alone and several installations had been in operation for considerable periods, including the first four-colour installation of the Rayon Federation. It was intended, however, that the system would be applicable to actual stage work as soon as the lamp manufacturers produced the necessary coloured lamps, and in that respect the developments of recent months had greatly advanced the objective.

Another aspect of the d.c. saturated choke was to produce a board of dimensions comparable with the electronic board and, vitally important, comparable in price with that of the simple resistance board; and to include the advantages of electrical mastering, pre-set applications, etc., with special application to small halls, schools, etc. To that end, he and his associates had designed such a board with dimmer levers on 1¼ in. centres controlling either a 1-kw choke or a 2-kw choke with a maximum control energy of 10 and 15 watts respectively and a current full/dim ratio of 11 to 1, giving satisfactory dim-out at 50 per cent. full load operations. The choke size was reduced to a gross weight of 22 lb. for the 1-kw and 33 lb. for the 2-kw, approximately. A further advantage of this type of board was that the tungsten chokes could be interchanged with the fluorescent dimmer which had a current full/dim ratio of 2,000 to 1 for effective control and required a full-up energy of 8-watts with a weight of 13 lb. Thus the same board, at will, might have fluorescent and tungsten lamps on together, all controllable through the same circuits. A further advantage of the d.c. saturated choke for fluorescent dimming was that the percentage of light output was directly proportional to the d.c. volts applied.

THE PRESIDENT (Dr. J. N. Aldington) said that a great deal of research was going on into this problem of theatre stage lighting particularly in respect to light source developments and he hoped the delegates would not leave the meeting thinking that there was any immediate possibility of fluorescent lighting being developed to produce much more intense light sources. There was no indication of that at the present time.

As regards the question of heat it had to be remembered that the conversion of electrical energy into light was a conversion which, while highly efficient from the total energy point of view, was always extremely inefficient from the light production point of view and, in any case, all the radiant energy ultimately went to heat so that, whatever light source might be developed in the future, when the radiation fell on the set it would be degraded ultimately to heat. The conversion of one watt of energy might, theoretically, give something of the order of 600 to 700 lumens but in practice there was apparently a practical upper limit of roughly 10 per cent. of that value for the region of the visual spectrum, so that there would always be 90 per cent. of the watt conversion manifesting itself as heat. Nevertheless, there were

indications in the research field of source developments which might assist in reducing the total wattage required to produce a given illumination. He issued a warning that in this work, while some newer sources appeared very promising, it was often at the expense of considerably more complication than existed at the present time. Therefore, much of this experimental work might remain in the laboratories for many years until the great problem of simplicity had been more effectively solved than it was at the present time.

He could not help feeling that as regards the pre-focus cap which had been available on many types of lamp for some twenty or thirty years there must have been some lack of persuasiveness on the part of Mr. Applebee if it had not yet reached the theatre!

DR. J. W. STRANGE, referring to control by means of the grid controlled rectifier, asked the author if there had been any marked developments in the reliability of that circuit.

After remarking that the question of maintenance was a major problem, he referred to the fluorescent lamp and the questions of heat, consistency of control, colour, etc., and said these questions were all met to quite a considerable degree by the use of lightweight fluorescent fittings. The difference between the heat emitted by tungsten lamps and fluorescent lamps had to be experienced to be believed. One had only to walk between banks of tungsten lamps and banks of fluorescent lamps in the Life Test Section of a lamp factory to appreciate the much greater heat output from the former, and also the extremely high light intensity which could be endured from fluorescent lamps without discomfort.

As regards the rough surface of the cyclorama, mentioned by the author, he said he could understand having a matt surface, but he could not understand why it should be necessary to have a rough surface; this must collect dirt and dust and be extremely difficult to clean.

E. WOOD (written contribution). As a supply engineer, I am pleased to learn that stage lighting installations are reasonably well balanced across the three phases where three-phase supplies are available. One would assume that the larger installations would be supplied from a transformer situated on the premises, and, if this was the case, the kVA capacity per phase would have to be equal to the largest single-phase load. If the balance were poor, one or both of the other transformer phase windings might be only lightly loaded. This would not make for economical operation since all the phase windings are identical. In spite of the fact that some people do not agree, Electricity Undertakings have to be operated on sound economic lines and capital outlay for transformers supplying single-phase loads balanced across the three phases of a transformer secondary must be less than that for the same single-phase load, which was very much out of balance. Another point which should be borne in mind when single-phase supplies are taken from four-wire three-phase circuits, is that of dangerous conditions arising from the possibility of medium voltage (400) between outlets in close proximity.

Mr. Ede in his remarks referred to the "Theatre Industry." I take it that stage lighting does not come under the jurisdiction of Regulations for Industrial Premises, but I would like to ask Mr. Applebee if there are any regulations which are statutory. So far as I am aware, the recommendations contained in the Manual of Safety Requirements in Theatres are not statutory.

It is not always easy to obtain a good balance of the stage lighting and at the same time ensure that points between which medium voltage exist are far enough apart to prevent the likelihood of dangerous shock. In spite of what I have said

about balance from the Supply Authorities' point of view, in my opinion safety is more important than balance.

Some speakers have referred to the wastage of electrical energy in the dimmers. Would it be possible to arrange to dim the lighting by means of tapped reactance? It would have the advantage of the wastage being wattless, but perhaps the initial cost would be too high and possibly it would not be sufficiently flexible. Then again, if reactance control were used, there is the possibility that the Supply Authorities would require power factor correction.

MR. APPLEBEE, replying to the discussion, fully agreed that simplicity was important; and as to the "Spotlight," he had mentioned in the paper that the intention was to focus the attention of the audience unconsciously on the point to be emphasised.

He was rather amazed that it had been said there was nothing available for small halls, because for every inquiry he received for equipment for larger theatres, he received 10 to 12 for the small halls. There was a switchboard with dimmers sold at from £35 to £50, whereas a big manually operated switchboard such as used at Stratford-on-Avon would cost to-day £2,000. The manufacturers had apparatus suitable for small halls; the trouble was that insufficient money was there to buy it, however inexpensive it might be.

Admittedly consoles were for the large theatre, where there must of necessity be a tremendous number of circuits which must all be under the control of ONE operator; but he must disabuse Mr. du Garde Peach of the idea that the console was complicated to operate. At the London Palladium the console was placed in the auditorium and was operated by a girl, and she was so quick that, at rehearsals, almost before the producer had completed his request, the effect was there for him to see. Once an operator understood the console there was no need for electricians running around the place to control the lighting, as had been suggested.

As to light sources, those concerned with stage lighting equipment appreciated the difficulties of the lamp makers. The biggest bugbear, however, was that with the A.1 projector lamp it was not possible to go beyond 22 deg. from the vertical. Theatre managements did not mind paying for a new lamp frequently, but what the producer was concerned about was that the guaranteed life was only 50 hours, and a lamp failing frequently on an important spot lantern was a worrying problem. The alternate lamp, the B.1, has a life of 800 hours, but its lumen output is much less, the filament being far less concentrated. The American lamp makers and stage lighting people had a projector lamp of about half the size, with a life of 200 hours, which could be burnt at any angle; also the lumen output of the unit could be increased because the reflector could be wrapped round the lamp ellipsoidally instead of using the ordinary spherical reflector.

He was well aware that the pre-focus cap had been here for many years, but the trouble had been to get the lamp manufacturers to seriously make and stock 500- and 1,000-watt A.1 or B.1 projector lamps so fitted; he was pleased to say this trouble was now overcome.

As regards the saturated choke, some equipment makers saw more advantage, both in operation and efficiency, for the electronic control. With the electronic control there was proportional dimming, and the problem of heat dissipation was wiped out, whilst the automatic balance of load on a three-phase-size supply was a big advantage. Of course, the electronic board, like the console, was only for the big theatre where there were very many circuits. This did not mean that the producer was using them all, but that plug circuits were distributed all over the place, and this resulted in a great saving of time and in a flexible installation.

As to the rough surface of the cyclorama, this broke up the light and helped

to diffuse it; and it had been found, in actual practice, to give the illusion of looking into space much better than a smoother surface.

He did suggest that Mr. Hodgkinson had inadvertently referred to the electrician as lighting the scene, and really intended to use the word producer. The producer states what he wants, and it is up to the electrician to use his ingenuity and skill to provide it.

On the question of improved colour media, he mentioned that the new plastic material mentioned in the paper was already widely used in the professional theatre, and is at the moment the most efficient available from the point of view of fading, durability, imperviousness to moisture, and is non-inflammable.

As regards making things having stereoscopic relationship to each other, Mr. Applebee likened directional lighting to the "contrast" control on a television set.

In reply to Dr. Strange, there was no difficulty in the maintenance of the electronic system, providing precautions laid down by the valve manufacturers are carried out. The use of fluorescent lamps as light sources for the stage is best answered by the question, "Does it give what Mr. du Garde Peach asked for," namely directional lighting? When it does the heat question might be answered.

In the matter of Mr. Woods's written communication, the balance on the layout of a stage is not, from a paper balance view, very difficult if one knows the "working" of a stage. One has to be careful, whether it is a front cloth or a full stage, that the balance is within reason. In practice the working balance works out quite well. One must take all precautions against, for example, the possibility of close proximity of circuits on opposite phases. For one instance, all connections on the floor of the stage MUST be on the one phase only. How the connections are used and apparatus connected up to the various plug points is the responsibility of the resident engineer who, according to the licencing authorities, must be a competent engineer. Three-to-one-phase transformers are not necessary.

One big advantage of the electronic control system is that no three-phase occurs on the stage. Each circuit is balanced and converted to two-wire D.C. 230-volt before leaving the valve bank supply. Safety from shock is thus avoided.

As regards statutary regulations, all theatre installations are carried out generally to the I.E.E. rules and the regulations of the local licencing authority. The manual of safety requirements in theatres is published by the Home Office as a *guide* for licensing authorities.

Those who were keen on stage lighting and wanted to see it used as it really should be used should see "Measure for Measure" at the Stratford-on-Avon Memorial Theatre. That was the finest illustration at present of how stage lighting should be done.

The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.

With a view to avoiding possible confusion with other publications, reference to these Transactions should be in the form :—"Trans. Illum. Eng. Soc. (London)."

The Development of Street Lighting in Great Britain

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Summary

The development of street lighting in Britain is traced from the twenties, when it was treated as an illumination problem, to the present day. A series of milestones marks the progress made, beginning with the British Standard Specification of 1927, and the Sheffield experiments and the I.C.I. meeting in America of 1928. The most important was the coming of electric discharge lamps in 1932; they resulted in new studies and a fresh approach to the whole problem beginning in 1934. Another very important event was the issue of the Ministry of Transport Departmental Committee's Report in 1937; 1939 marked not progress but regress, for public lighting in Britain ceased for ten years. In the post-war period there has been some technical progress and the coming of tubular fluorescent lamps, and improved lanterns.

The present notions of the theory of four systems of lighting—non-cutoff, semi-cutoff, cutoff, and unidirectional systems—are described and a brief review of modern lanterns is given. The outstanding problems of street lighting are stated.

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(1) Introduction

Street lighting began in Great Britain in the sixteenth century, with the requirement that "every householder . . . should cause a substantial lanthorn with a candle of eight in the pound to be hanged without their doors." The arrangement, if it was complied with, probably gave more light than might be supposed—about half the light that is provided in many residential streets to-day, and a much shorter spacing. The history of these early attempts is available to those interested and need not be given here; the present paper is concerned with the more recent development of street lighting as a branch of Illuminating Engineering.

This might be said to begin with Trotter, who was one of the first to study the subject formally in this country. He devised instruments for its measurement and designed some of the earliest street lighting refractors, and he was chairman of a

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committee charged with its standardisation. The present review begins rather later, in the early 1920's, when the practice of electric street lighting had become established using the tungsten filament lamp, although the greater part of street lighting in this country was then by gas.

Since the author is not familiar with gas practice, he may be pardoned if he refers to electric practice in those parts of the paper which are concerned with the light source. Many of the developments recorded are independent of the illuminant, and important work has been done by both gas and electrical engineers.

The technical progress of street lighting has been marked by several milestones. At each of them technical thought and approach has taken a new turn, and fresh understanding has been gained of the "mechanism" of street lighting. The milestones have in three instances been the preparation of official documents relating to the specification of street lighting or a code of practice for carrying it out; but it is important to recognise that milestones are not progress in themselves; they only mark progress. Sometimes a more exact simile would be a signpost, indicating a change of direction; for each time an official pronouncement appeared, it affected and directed progress made by those commercially concerned in the supply of street lighting apparatus. The direction was sometimes unexpected, for such pronouncements provoke a peculiar perversity and may send developments off on an unforeseen course.

(2) Street Lighting in the Early 1920's

For a good many years street lighting was considered very much in the same way as other tasks of lighting, as a matter of getting as much light as possible on to a working plane as evenly as possible. Success in doing so was taken as a measure of the virtues of the installation. The problem was complicated by the long spacing and comparatively small mounting height available, and hindered by the absence of walls and ceilings which contribute so much to interior lighting; but it was approached in the same way. In interior lighting it was customary to adopt a working plane 3 ft. from the floor, and for some time the same convention was used in streets, although obviously no such physical horizontal plane existed. When the author first made acquaintance with street lighting it was customary to calculate and quote the illumination of a plane 3 ft. from the ground on a line between two lanterns, for which convenient tables of $\cos^3\theta/h^2$ were prepared for various values of h, and short-cut methods of calculation were devised. It was thought later that average illumination would be a more valuable quantity as a figure of merit, if it could be ascertained; but it was a nuisance to calculate, and more ingenuity was expended on methods of arriving at it quickly. Electric lanterns then almost always used tungsten filament lamps, often with, in main streets, prismatic bowl refractors, or band or dome refractors, giving either symmetric or asymmetric distributions. Their design was studied in detail, but always with the aim of producing better and more nearly uniform illumination. Haydn Harrison, one of the early pioneers, devised some unconventional asymmetric lanterns, such as the "LL" lantern (the optical principle of which has recently been turned upside down and used for an aerodrome contact light) and the "Bi-multi" reflector, which is still much used to-day in various forms. He was also responsible for a flicker photometer for measuring street lighting.

(3) The First Milestone: B.S.S. 307, 1927

The first milestone was the British Standard Specification of 1927 (1), which recorded the state of the art at that time. It specified eight British Standard Classes of Installation, each characterised by a specified minimum mounting height, maximum spacing-height ratio and minimum illumination, and other provisions. Of these the specification of minimum illumination was the most important, for it set the stage for street lighting development for some time to come. It was not intended that

the minimum illumination should be considered as a figure of merit for the installation, but only as a rating, indicating its " calibre " or " bigness " as say the rating of an electric motor in horsepower does (2); but inevitably it was regarded in practice as a figure of merit, and since it was the principal photometric requirement the attention of designers of equipment and installations was concentrated upon it. The minimum illumination was selected as a rating for several reasons; it was fairly easy to measure and to specify, and to calculate for design purposes; its provision ensured that designers made an attempt to spread light over the street surface, and did not use too long a spacing. As a further safeguard, maximum spacing and spacing height ratios were laid down. Experience showed that although minimum illumination had no theoretical virtues and was not intended as a figure of merit, on the whole streets with a low minimum illumination were less satisfactory than streets with a high illumination, always provided that the illumination was achieved by the methods envisaged in the specification and with the safeguards laid down.

The effect of the specification, and of its revision in 1931, was not, however, altogether as expected. There was too much attention given to the " test point," with the result that light distributions appeared which produced beams of light spot-lighting the test point and which were not contemplated when the specification was drafted. In spite of all warnings, the test-point illumination was regarded as a figure of merit, and anomalies were inevitable.

A great deal of attention was paid in the early specification to glare. It has always been the bugbear of street lighting, and it still is to-day. The work of Bordoni, Holladay and Stiles was becoming available, and Walsh devised a method of calculating glare for the purposes of the specification which was included in the 1927 specification. It provided for the calculation of a glare figure for a given distribution, and it was based upon Stiles' and Holladay's work on disability glare. At that time there was little information on the brightness of the field of view in lighted streets, and an assumption was made of the reflection properties of the street surface which was seriously in error; it resulted in the adoption of much too low a field brightness, and in consequence gave an undue emphasis to the effects of disability glare which has persisted ever since.

But although illuminating engineers continued to design installations on the basis of illumination, knowing no other, some of them were becoming aware of inconsistencies between calculation and experience. Preston Millar, in America, had pointed to the importance of brightness rather than illumination (3), and measurements of the reflection properties of road surfaces had been made by N.P.L. and elsewhere; but nobody knew then how to use these ideas.

(4) The Second Milestone: 1928

In 1928, Mr. J. F. Colquhoun was elected President of the Association of Public Lighting Engineers; and the International Illumination Commission met at Saranac Inn in America. Those two events combined with the B.S. Specification of the previous year to give a great impetus to British street lighting. The major credit must go to Mr. Colquhoun. For the purpose of his Presidential Address (4) he had erected in Sheffield no fewer than 52 special street lighting installations, gas and electric, of all magnitudes from the smallest to the greatest; installations which kept the rules and some which broke them. Their illuminations and other data were measured and tabulated, and they provided a unique opportunity for experiment. A good deal of thought was being given at that time to the problem of visibility (5), and it was possible to test theories in a whole range of calibrated installations. The delegation which went to America and put there the case for the British Standard Specification had some sound ground for their opinions, and the case for minimum illumination,

as at least a measure of the size of the installation, was made with a good deal of conviction, although the British opinion was in a minority (6).

But the Sheffield installations produced some anomalies. There was one in particular, a little street called Windyhouse Lane (Fig. 1), which had a type of lighting fitting which some experts then profoundly distrusted. By all the rules it ought to have been very glaring, but it was not. The answer eluded the experts; they filed the question for future reference. However, out of experience at Sheffield and elsewhere and with models, some of the rules of good practice were emerging, such as the effects of the road surface, the importance of placing lanterns on the outside of bends, and some of the phenomena of visibility.

Fig. 1. Windyhouse Lane.

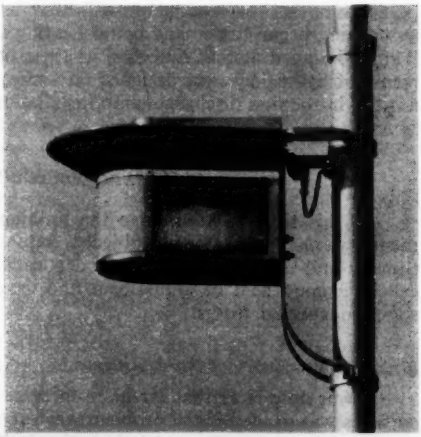
In the next three years lantern designs were improved and new refractors produced; at the same time further intensive studies were made of visibility and glare, notably a careful experiment by Stiles in streets at Leicester, at the next annual meeting of the A.P.L.E. (7), which threw doubt on the disability glare criteria of the specification, and emphasised the relative importance of discomfort glare. The B.S. specification appeared in revised form (8) without the glare calculations, but with a method of calculating average illumination, the value of which it required to be stated in the tender. Some refinements were made in light distributions; for example, Wilson found that there were advantages in making the polar curve of intensity distribution "flat-bottomed," which avoided a curious and objectionable apparent shadow on the road—an elusive effect dependent on the surface reflection properties, not then understood. More methods of calculation were worked out for use with the B.S. Specification, and for the determination of average illumination on the carriageway (9).

(5) The Third Milestone: Discharge Lamps, 1932

In the meantime, lamp developments had been taking place rapidly. On the Continent, Pirani and others were busy with the sodium vapour lamp, and in this country Ryde (10) and his associates were developing the high-pressure mercury vapour lamp, both having in mind the use of the lamps for public lighting. The two lamps led to two methods of approach to the lighting problem and sharply divided the practice in this country and on the Continent, as we shall see. In Britain the designers were faced with a lamp unlike anything they had handled before. It could then be burned only with its axis vertical, and the arc which was the actual light source was about six inches long. Designers accustomed to the filament lamp with a light source of

small vertical height, and imbued with the idea of preventing glare at all costs, particularly by reducing the candlepower quickly above the peak, faced this challenge with something like despair. Various peculiar lanterns were devised in a vain attempt to control the light, and eventually a new refractor lantern was produced (Fig. 2) with a good deal of misgiving. It was the first lantern in the world designed to be used with H.P.M.V. lamps for public lighting, and much hung upon its performance. It gave a good maximum intensity in about the right direction, but above the peak no ingenuity could restrain its exuberance. The prophets foretold dreadful glare. The only possibility of reducing the glare was by an expensive and inefficient arrangement of louvres, which it was desired to avoid if at all possible, but they were manufactured just in case. Eventually the time came for the installation to be switched on, and it was first put in lighting at the dead of night, for the benefit of its designers only, with the louvres ready for addition should the predictions prove to be right.

But the prophets were wrong.



(Right) Fig. 2. Early lantern for H.P.M.V. vertical burning lamps.

(Below) First public installation of H.P.M.V. lamps.

The installation was a success beyond all expectation, and the louvres were thrown away, all except one on a railway bridge, where it is to this day. The road surface appeared as a ribbon of light, visibility was excellent and the glare was not at all excessive (Fig. 3). But nobody knew why.

The coming of discharge lamps marked the most important turning point in the history of British street lighting. Engineers were presented with lamps with almost the simplicity of the filament lamp, with three times the efficiency and twice the life. Public lighting could be provided on a scale and to a level which was previously not economically possible, and which brought good night visibility on main roads within

the reach of most municipalities. Developments were taking place in gas lanterns also, of which the gas industry may well be proud, but the author is not qualified to discuss them. They were, in the nature of things, on a less spectacular scale, and had less effect upon the development of street lighting, but they should be included in any record of progress.

The discharge lamps gave light of an unfamiliar colour, which had strange and unflattering effects on personal appearance; but that was not altogether a bad thing. Perhaps if they had given light of the same colour as filament lamps less attention would have been given to them. As it was, every new installation was a matter of public interest and comment, with the result that people, and through them local authorities, began to demand better lighting and to be prepared to pay for it. The installations designed at that time had as their object good visibility and the impression of plenty of light; they were designed on a new theory which was stimulated by the effects noticed in the first discharge lamp installations, and which was itself another milestone.

(6) The Fourth Milestone: 1934

By this time, a solution to the problem was urgently needed, and many experiments were made. Test objects were tried by various experimenters in this country and abroad; Wilson's wooden cats were perhaps the most notorious. They caused a good deal of amusement and gave few quantitative results, but they taught some unexpected truths.

(6.1) The Properties of Road Surfaces

It was now clear that far more information about the reflection properties of road surfaces was needed if the problem was ever to be solved, and studies were made both in France by Cohu ([11]), and independently in this country by the present author, using different techniques. Cohu obtained data on five surfaces, samples of which he removed from the road to a specially constructed laboratory: the present author measured three surfaces *in situ* by a method of photographic photometry. In a paper to the Association of Public Lighting Engineers in 1934 ([12]), the results and methods were described and their influence was explored; the reasons for the anomalies began to be found.

The reflection properties of road surfaces are very complex at the angles which are of interest, and their determination, at angles of incidence and view sometimes less than one degree from the plane of the surface, presented special experimental difficulties. They had to be determined not merely in one plane but in three dimensions, and, indeed, the complete presentation of the properties of a road surface calls for a series of families of curves. Not the least difficulty in tackling the problem is that of handling this mass of information, especially when it is recognised that it is entangled with the three-dimensional light distribution of the lantern and the three-dimensional geometry of the street and the observer. In such problems it is easy to get bogged down.

(6.2) The Use of Perspective Geometry

Fortunately, the British work was led, from its use of photographic techniques, to use perspective geometry, and our whole approach was based upon it. This approach turned out to be one of the most valuable conceptions in street lighting, and one which has done much to unravel its peculiarities. The geometry of street lighting is unlike that of almost any other lighting problem, and it is unlikely to be understood if approached by the conventional use of plans and sections. The approach by way

of perspective automatically concentrated attention in the right places and confined experiment to the regions which are important; it greatly simplified the whole problem.

(6.3) The New Explanation of the Mechanism of Street Lighting

There resulted a new conception of the mechanism of street lighting ([13, 14]). Previously it had been considered as a problem in illumination; the installation was conceived as built from "units of system" or "spans" viewed in plan, each with certain lanterns illuminating it in concert. This was the basis of the B.S. Specification. In the new approach, the idea of the unit of system was abandoned, for a study of road surfaces had shown that the effect of a single lantern often extended far beyond the unit of system in which it was situated; in fact, the unit of system corresponded to nothing concrete in the field of view. The street was now considered as a perspective view instead of a plan, and attention was turned from illumination to brightness. In fact, in 1935 in this country we took in street lighting almost exactly the same line as is now being taken in school and office lighting in America, where they are studying brightness in the field of view and the reflection factors of significant surfaces rather than the illumination of a hypothetical working plane.

The total effect as seen by a road user was considered as being the sum of the effects of the individual lanterns. The contribution of each lantern to the brightness of the field of view was calculated separately, and the whole field built up from them in perspective.

This principle is fundamental, and it applies to any system of street lighting whatever, whether cutoff, non-cutoff, or any other. It amounts to no more than the axiom that the whole is equal to the sum of its parts; its only merit lies in its recognition of what the "whole" is in which we are interested, and what are the "parts" of which it is built. The older approach attempted the same thing, but it mistook the "whole," and tried to build it from the wrong "parts."

It was found that in general any lantern placed over the road surface results in a bright patch on the surface, the distribution of luminance in which can be calculated from the light distribution, the reflection properties of the surface and the geometry of the arrangement. If the light is not subject to any cutoffs, the bright patch has the form of a letter T, with a head and a tail (Fig. 4). The luminance distribution and the sizes of the head and tail depend upon the light distribution and the reflection properties, the latter predominating. They also vary with the geometry, particularly the distance of the lantern and the mounting height. These patches

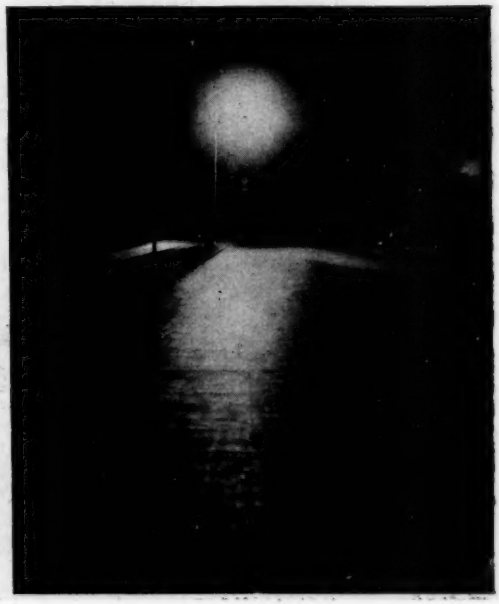
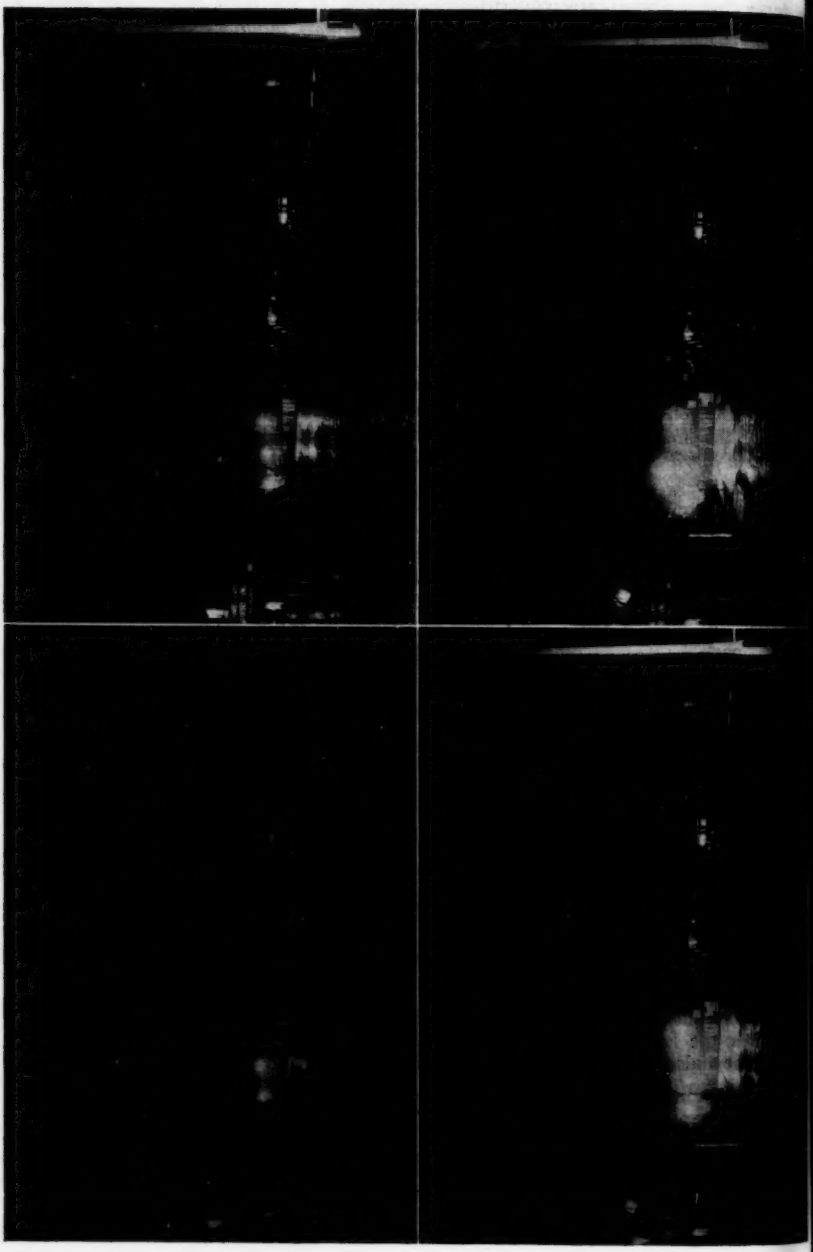


Fig. 4. Typical bright patch from one lantern: non-cutoff distribution.



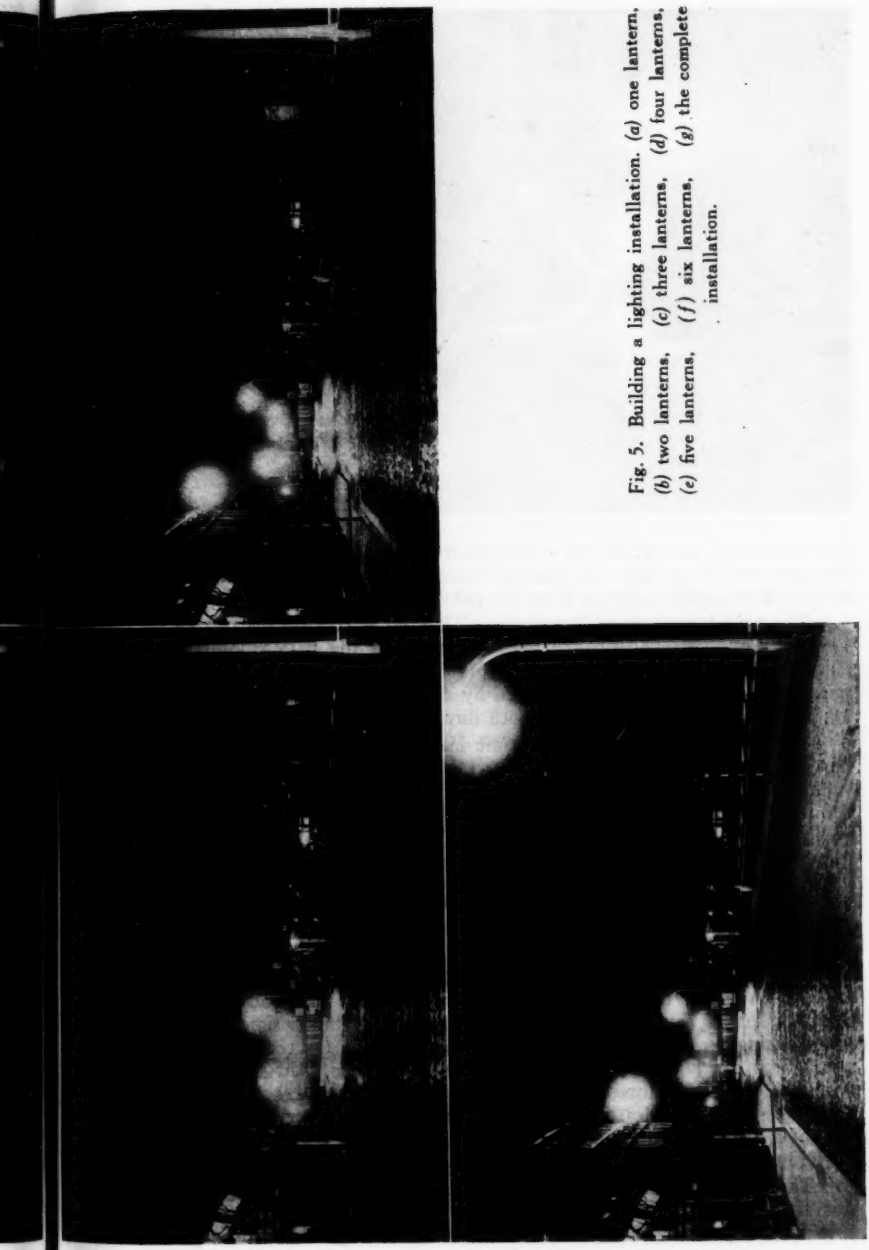


Fig. 5. Building a lighting installation. (*a*) one lantern, (*b*) two lanterns, (*c*) three lanterns, (*d*) four lanterns, (*e*) five lanterns, (*f*) six lanterns, (*g*) the complete installation.

Fig. 6. Effect of change in light distribution. Left-hand half: peak at 85 deg. Right-hand half: peak at 72 deg.

are the bricks from which the road appearance is built; the success of the installation depends upon how truly they can be laid. Fig. 5 shows how an installation is built up by the successive addition of bright patches as lanterns are switched on successively.

The bright patches are not stable. They lie always on the observer's side of the lantern, and move and change with his position; the pattern of patches shifts and changes as the observer moves down the road. To light a winding road well, the position of the lanterns must be fixed by careful compromise, to cover the road from all important viewpoints and for both directions of traffic; such planning is an art.

The anomalous behaviour of some installations was now explained. The tail of the T, which includes the brightest part of the patch, was found to be formed by a very small region of the light distribution, lying a little above the region responsible for illuminating the unit of system in which the lantern is situated. In fact, the tail of the T is formed by the very region of the distribution which is also responsible for causing glare from the more distant lanterns. In the older lanterns, to reduce glare, the light distribution was usually designed with a partial cutoff or "runback" in this region, just above the peak of the distribution; and this "runback" was achieved with more or less success in various lanterns. Its effect upon the appearance of the road surface was unsuspected. When the cutoff was achieved, it not only cut off the glare but it cut short the tails of all the bright patches, so that they had little, short tails which failed to meet the adjacent patches, and the road appearance was consequently patchy and its brightness low. But when the designer was less successful in producing the cutoff above the peak, the patches on the road often had long, bright tails which overlapped and joined patch to patch; the road surface was then nearly uniformly bright. Moreover, the brightness which could be so achieved was very high, for at these angles the luminance factor of the road surface can be many times that of a surface of snow, and even very distant lanterns can contribute appreciably to the luminance, though their contribution to the illumination is negligible.

The effect can be seen in the early experiment illustrated in Fig. 6. In this installation the right-hand half is lighted by the type of distribution previously considered good, with a peak at 72 deg. aimed at the test point region and a sharp fall of intensity

above the peak. In the left-hand half the peak has been raised to 85 deg. by adjusting the lamp, in a way which would at that time have been condemned. The effect upon the individual patches can be traced, and the much more nearly uniform appearance of the road surface will be noted. The illumination at the test point was, however, diminished to nearly one-half of its former value. In the opinion of road users and of the local surveyor, the glare, though increased by the alteration, was quite acceptable and the installation was improved; the refocusing was made permanent throughout. It should be observed that so high a peak angle is unnecessary and is not recommended now.

(6.4) Glare

The glare effect can also be explained. Hopkinson found later ([24]) that for a given lantern the glare is markedly dependent upon the luminosity of the field of view. If the road surface is used in this way, its luminance can be greatly enhanced for a given light output and for a given glaring intensity, and it often happened that the net result was a greatly improved road appearance without any serious increase in glare. In the early days this happy combination sometimes occurred by accident; sometimes indeed by what was then considered bad design. In both the little installation in Windyhouse Lane and in the first H.P.M.V. installation, the candle-power above the peak was maintained, and with the road surface in use a very good result occurred. But clearly, at ordinary spacings, the occurrence of glare will depend very largely upon the road surface. Most of the glare is due to the nearest lantern and to light emitted at about 75 deg.; only that from the more distant lanterns is due to light emitted at 80-85 deg. Nevertheless, cut down the intensity in the region 80-85 deg. and this glare will be reduced, but the installation will be patchy and dull. Increase the intensity in this region and the road surface will become bright but the glare will increase. If the surface is suitable the increase in brightness will be so great as to defeat the glare; if it is not, the glare may defeat the road surface brightness. Many road surfaces enable this property to be exploited, and some fine installations have resulted. The glare is also markedly affected by the nature of the surrounding buildings.

This discussion of the mechanism of street lighting is obviously incomplete, inasmuch as it takes no account of such factors as the kinematic effects, or of such vital matters as the outlining of the kerbs and footpaths and the revealing of junctions and roundabouts, which there is not space to include. It refers only to traffic routes and to the requirements of drivers. A valuable study of kinematic effects was made by Davies, Lucas and Maxted ([15]); Smith, Sawyer and Winslow ([16]) studied the properties of kerbs and the conditions for revealing them, and Smith and Sawyer ([17]) made some fascinating studies of visibility in traffic with the aid of a film camera on a car. It is most important to keep all these factors in mind, lest we simplify the problem out of existence; the simple mechanism outlined here does not touch many important parts of the problem.

(6.5) The Continental (Cutoff) System

While these developments were taking place in Great Britain, based upon the H.P.M.V. lamp, the sodium lamp had appeared on the Continent, and brought with it a system of street lighting which soon spread to England. The first sodium lamps were rather complex and required both A.C. and D.C. supplies, but they soon assumed the long, horizontal form familiar to-day. While the mercury lamp could not be burned horizontally at that time, the sodium lamp could be burned only in that position; and this may have contributed to the development of another lighting system diametrically opposed to the one which was developed for the H.P.M.V. lamp. On the Continent the first requirement was not high road brightness, but low glare.

Instead of emitting more light above the peak of the light distribution, they formed an even sharper and lower cutoff, so low that a driver was prevented from seeing any glare at all, partly by the lantern cutoff and partly by the hood of the car. There resulted patches on the road, the tails of which were quite amputated; they consisted of a head only, and looked like a bright band across the road, and to build up a bright road surface from them the lanterns had to be centrally mounted at a very close spacing. As will be seen below, the freedom from glare was purchased at the price of lower road brightness for a given power, and certain other disadvantages; but the comfort and attractiveness of the result cannot be questioned. The cutoff system very soon became known in this country, first in the well-known installation in Purley Way, and then under the determined leadership of P. J. Robinson at Liverpool. It is now becoming much more widely used, and it or some modification of it may well be the system of the future (Fig. 7).

Fig. 7. Cutoff lighting on double carriageway road: dry surface. The outer kerbs are 61 ft. apart.

Although initially the sodium lamp was associated with cutoff lighting and the H.P.M.V. with non-cutoff, the lamps and the systems are not tied together and can be interchanged; excellent cutoff lighting has been carried out with H.P.M.V. lamps, and sodium lamps have been used more with non-cutoff than with cutoff lighting. Each system can use any of the common illuminants.

(7) The Fifth Milestone: The Ministry of Transport Departmental Committee: 1935-37

Concurrently with the developments described in the last section, another step was being taken which has had perhaps the greatest effect upon the practice in this country. The Minister of Transport set up a Departmental Committee in June, 1934 "to examine and report what steps could be taken for securing more efficient and uniform street lighting with particular reference to the convenience and safety of traffic and with due regard to the requirements of residential and shopping areas, and to make recommendations." This committee proceeded energetically; it heard evidence from many bodies and made many inspections of existing installations. It also set up an elaborate test installation upon which full-scale experiments could be conducted, and had the assistance of an experimental panel, consisting of experts from the National Physical

Laboratory, the gas industry and the electrical industry, under the chairmanship of Mr. A. E. N. Taylor, of the Ministry.

This committee was set up at a critical period, when new ideas were just appearing and when the established ideas were being questioned. It was able to consider the administration of street lighting on a national scale, which brings at least as many problems as the technicalities provide. The recommendations of the M.O.T. Departmental Committee [18] differed sharply from the practice enshrined in the British Standard Specification, and they have set the standard for British street lighting since.

Their recommendations are well known; the principal ones are recorded here for sake of completeness. The most far-reaching was the decision to recommend two, and only two, classifications of installation instead of the eight of the specification; they were to be used for traffic routes and for "other roads requiring lighting" respectively. They were distinguished principally by the mounting heights, which were 25 ft. and 15 ft. respectively. The intention was that the traffic route installations should be sufficiently good for drivers of motor vehicles to proceed safely without the use of headlights; the committee took the view that there was no point in providing installations which were *nearly* safe. The sharp reduction of mounting height in "other roads" was to serve as a clear indication to the driver that the lighting was no longer intended to be sufficient for him, and that the onus was upon him to use headlights if necessary.

The committee abandoned the criterion of illumination at the test point which had been so thoroughly tried by the B.S.I., for by that time so many anomalies had been found that its value was doubtful. They proceeded by laying down, in broad terms, the height and positions at which lanterns were to be mounted, and, within fairly wide limits, their power, rather than by attempting to specify the result to be obtained. They insisted that the decision whether a given road was a traffic route or not, and where in the recommended range of power the installation should lie, were matters for local decision, and they avoided any attempt to specify visibility or any other attribute of the installation.

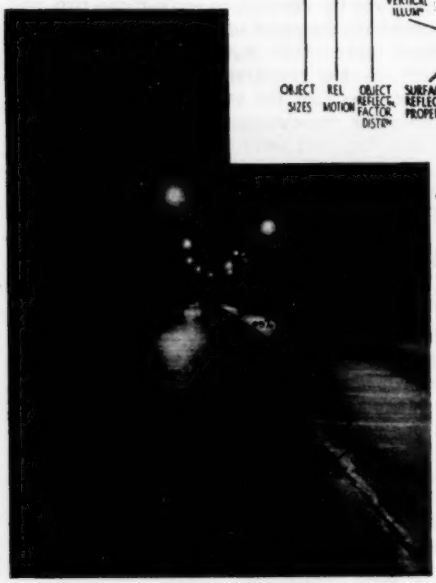
Their avoidance of these qualities was not due to any fading of interest in them, but rather to a better understanding of their nature. The experimental panel had made a very thorough and detailed study of the problems of visibility, and had produced a new theory of the mechanism of seeing on roads which was reported in three papers to this Society in 1937 by three members of the panel [19]. English and Stroud had meanwhile done similar work [20] on rather different lines.

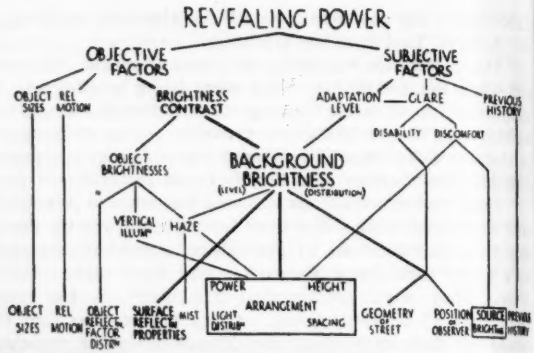
(7.1) Revealing Power

The work on "revealing power" was complex and unsuited to any kind of routine experiment, but it elucidated the mechanism of seeing and indicated what was possible by way of specification. It confirmed that objects were nearly always revealed in silhouette, dark on a light ground, and showed how the chance of seeing an obstacle depended upon the brightness difference between the obstacle and its background; how the chance of the obstacle brightness lying within certain limits could be found from the frequency of occurrence of various reflection factors of objects, and distribution of illumination upon vertical surfaces within the unit of system. The unit of system thus now became important again, but in a different connection. Dunbar organised some classical experiments which determined the least necessary difference in brightness which a driver needs for the safe seeing of objects when he is actually driving a car, and Smith studied for the first time the statistical distribution of reflection factors of pedestrians—work which was later extended in the Netherlands, and in America by Moon and Cettei [21]. The present author studied the combination of these results with the brightness of the field of view and showed how the driver's field of view could be "contoured" to give the "revealing power" in its various parts (Fig. 8). The

(Below) Fig. 8. Installation contoured to show revealing power.

(Right) Fig. 9. Factors in revealing power. Only the factors in boxes are in the engineer's control.





" revealing power " at any point in the field of view is the percentage of all possible objects, in all possible positions in line with that point, which will present sufficient contrast to be safely visible to a driver.

The most important conclusions of this complex study were (i) that the revealing power is largely dependent upon factors which are very variable and quite outside the control of the designer or anyone else (Fig. 9), consequently any attempt to specify revealing power is nugatory; (ii) in broad terms, the achievement of high revealing power depends *upon producing a high brightness of the road and other surfaces without at the same time producing a high brightness of the objects on the road.* This conclusion is underlined, for upon it depends the effectiveness of any lighting installation, so far as revealing objects is concerned. From this it follows that the so-called " non-cutoff " system produces a high revealing power, if it is properly designed and if the road surface is suitable, because it exploits the reflection properties of the road surface to produce a high road brightness without greatly illuminating objects. (iii) It became clear that all the factors which operate to impair the revealing of objects take effect in the regions of low luminosity. A certain minimum level of luminance—about 0.07-0.1 footlamberts in non-cutoff installations—was found to be desirable to indicate with certainty that the road is empty.

The final report of the Departmental Committee, which appeared in August, 1937, was based for the most part upon the non-cutoff system. The cutoff system was then little used in Britain and there was not much experience of it; other systems, such as those for the lighting of double carriageway roads by unidirectional distributions, were only just propounded. Though the report did not specifically recommend these systems, it was able to make provision for them and to avoid requirements which would hinder their use.

(8) The Sixth Milestone—1939

It would be satisfactory to be able to report a further series of milestones recording more progress in street lighting. In July, 1939, the International Commission on Illumination received a paper by Paterson, Smith and the present author (22), which recorded British progress and which might have affected progress in other nations, but the 1939 milestone records regress rather than progress. "The lights went out all over Europe," and they have only just been fully relit in this country. The investigations made with such vigour ceased for 10 years; apparatus and teams were turned to other uses or dispersed, and now that full street lighting has been restored it is difficult to recapture the enthusiam of the pre-war years and to pick up the threads again. During the war there was street lighting, closely controlled by specification, requiring much novel experimenting and some curious methods of lantern construction. But the amount of light concerned would have been ignored as stray light in the most meagre peace-time installation, and little was learned about the lighting of streets from some years of hard work in this period.

Nevertheless, the interval has served some purpose. We have been able to review the progress made, and perhaps to understand it better, and in some ways there has been further progress; for example, Hopkinson, who in 1936 had devised a classical method of faithful portrayal of streets by photography (23), published in 1940 in the Transactions (24) an investigation of discomfort glare in street lighting which elucidated that controversial subject. Since the war there has been a good deal of progress in the use of cut-off systems, the use of sodium lamps, and the development of street lighting with fluorescent lamps, in which Britain led the world. It is perhaps too early to say whether the entry of fluorescent lamps into street lighting constitutes another milestone. Some fine installations have been carried out with them, remarkable for the excellent colour of the light and reduced glare; but no new principle of lighting is involved in their use.

(9) Specification, Code and "Yardstick"

It would be satisfactory to be able to record the implementing of the Report of the Departmental Committee into a British Standard Specification. It was the wish of the committee that this should be done, and the B.S.I. set out to do it. But the history of that attempt is unfortunate. After long work it produced a draft for comment, but the comments were adverse; eventually the committee changed course and attempted a code. But that, too, has had its difficulties and at the time of writing has not yet appeared, though there have been several dissertations on the relative merits of code and specification (25).

If a workable mandatory Specification could be produced, compliance with which would ensure a good installation and which would provide a proper basis for tender, everyone would be satisfied; and it is natural that public authorities have pressed hard for such a document. But in our irregular streets one cannot possibly be so specific. The new approach to the problems of street lighting has changed what was once a rather empirical science into an art, and one cannot specify an art. This is the root cause of the disagreements which have prevented the appearance of a Specification, and the author is convinced that no workable specification, properly so called, is possible. A code is possible, for a code lays down general working principles to be followed as far as practicable. The Committee Report constitutes a Code in effect, and the B.S.I. will, it is to be hoped, put the requirements of the Departmental Committee into more conventional Code form. The provisions of the B.S. Code, when it appears, may not vary very much from those of the Committee Report, for there

has not been very much further evidence forthcoming since its drafting; and the original provisions were based upon sound experiment and were good in principle.

For many years there has been a demand for some kind of "yardstick" with which the merits of a lighting installation can be gauged. Naturally enough, the authority who has invited tenders for an installation needs some means for appraising the tenders received, and when the installation chosen is in lighting, some means of finding out whether it has received what it has paid for. Some think that the yardstick is lacking only because knowledge of the subject is insufficient, and the experts have been upbraided when no yardstick was forthcoming.

The lack of a yardstick is not however due to ignorance, but to understanding. It is of no use to provide a false or ambiguous measure, particularly when matters of contractual obligation are involved; and enough is known about street lighting to be sure that very many of the most important factors which determine whether an installation will be good or not are out of control. From time to time so-called "visibility meters" make their appearance; but they do not measure "visibility" in the sense required, and their indications cannot be relied on and cannot be analysed. The only sound way of appraising the merits of a design is to compare it with the code of practice provided by the M.O.T. Report, or the B.S. Code, when it appears. An actual installation can be appraised only by examining it critically in various states of weather and with objects present. It is of course possible to devise tests of illumination for a particular installation, which will disclose whether the lanterns are giving their promised performance, but such tests cannot be generally specified.

In this, street lighting is no worse off than most matters of contract and purchase. There are very few in which it is possible to provide a real figure of merit, though it is often possible to make tests of performance in some specified particular. One can test the maximum speed, fuel consumption and braking of a motor car, but no overall figure of merit exists which will take into account such practical matters as ease of steering, springing, road holding qualities and the comfort of the upholstery, matters on which more often than not the car is sold. It would be wiser to rely on a specific performance test than to expect a figure of merit which we possess in hardly any other commodity.

(10) The Present Position

It is possible to summarise very briefly the present-day notions of the action of the various systems of street lighting now in use. This summary will necessarily be sketchy and lacking in detail, for a complete exposition would need much space. The following relates to traffic routes in the first place.

A principal object of the designer is to provide a fairly high and fairly uniform road surface brightness. This when achieved forms a background against which any objects can be seen in silhouette, and which clearly reveals the course of the road to the driver, giving him confidence in his ability to see. This should, of course, be achieved with as little glare as possible; the distinction between the various systems turns largely upon the means for avoiding glare and the importance which is attached to it.

The bright road surface and footway surface is built up by the superimposition of the bright regions produced by the individual lanterns, whatever system may be used, and it is convenient to distinguish the various systems and explain their action on this basis.

(10.1) Non-cutoff or High Angle Beam System

In this system the light distribution is characterised by the provision of fairly high intensities up to angles of a little over 85 deg. At this angle the intensity needs to be about two-thirds to half the peak intensity, which commonly occurs at a lower angle of

75 deg.-80 deg. (Fig. 10), and is commonly 2,500-4,000 candelas. Such a distribution produces on a normal road surface a bright patch with a long "tail," which is suitable for a staggered arrangement of lanterns having a spacing of 120 ft. to 150 ft. In such an installation the lanterns on one side of the road, forming a single row, are spaced at 240 ft. to 300 ft., and the bright tails are long enough to extend from one patch well into the next on the same side of the road. On bends, the lanterns are placed on the outside of the bend, so located that the bright tails lie side by side to cover the field of view. A gauge has been produced whereby the lanterns can be readily sited on a drawing, so that this result is achieved for reasonable road surfaces (26).

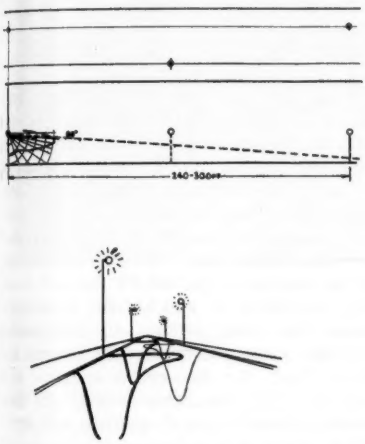


Fig. 10. Mechanism of non-cutoff lighting.

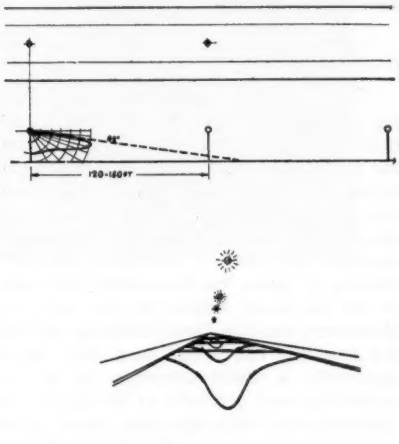


Fig. 11. Mechanism of Semi-cutoff lighting.

This system has been widely used in this country, and when well planned in suitable conditions it is very effective. It is economical, and is flexible, inasmuch as the spacing can be varied a good deal without producing patchiness—a characteristic which is invaluable in British cities, in which the roads are narrow and winding, with irregular intersections, and where the ground is encumbered with obstructions above and below the surface. The revealing power is high and the system cheap. There is, however, some glare, and with the rougher surfaces adopted since the war the glare has tended to increase and is sometimes justifiably criticised. It is to be emphasised, however, that this system has grown up in the roads of this country, which are in some ways unique, and that it was this system which made popular modern street lighting of high revealing power. The author regards it as a good utilitarian system, but not the ultimate. It is unsuited to very wide, straight roads (unless additional lanterns can be used in the centre) or to roads with very rough, dark surfaces which are likely to remain permanently so.

(10.2) Semi-Cutoff, Controlled Cutoff or Medium Angle Beam System.

In this variant of the non-cutoff system the intensity of the lanterns is maintained up to about 80 deg. and reduced to about 10 per cent. of its maximum by 85 deg.; the maximum may occur at 70-77 deg. (Fig. 11). The bright areas are now too short for the staggered arrangement at 120-150 ft. spacing, but they are long enough for opposite or centrally mounted systems at these spacings, for the spacing *per row*

is now halved. In such arrangements the controlled cutoff is superior, for if the non-cutoff system is then used the long tails are overlapped to such an extent that they build up to a very high brightness at the sides or centre of the carriageway, and everything else looks dark by comparison. This is specially to be avoided with centrally mounted lanterns, for the excessively bright centre distracts attention from the edges of the road and invites speeding along the middle. There is also an unnecessary amount of glare. Central mounting is discouraged unless rendered necessary, for example by trees; for it fails to reveal the kerbs well by any system, particularly the non-cutoff system. The controlled cutoff system, as here defined, is little used deliberately, because the conditions which demand it occur infrequently, but the distribution corresponds closely to that used in about 1927.

(10.3) Cutoff System

In the cutoff system there is a sharp fall in intensity above about 70-75 deg., the intensity becoming nearly zero by 80 deg. (Fig. 12). The bright patch on the road surface has now no tail at all, and appears in perspective as a bright band across the road. It is now the heads rather than the tails which have to meet; instead of laying the patches side by side in perspective, as in the non-cutoff system on a bend, they are laid together "horizontally" in perspective. This demands a short, regular spacing per row of lanterns; if the spacing is irregular or excessive, the appearance becomes very patchy. The chief merit of the system is, however, the almost complete absence of glare, for to a driver the view of the lantern is cut off by the car hood, or his hat brim, before he can see it in the directions in which light is emitted. Moreover, there is little build-up of brightness, since the patches do not overlap and they are less bright than with the non-cutoff system; therefore the system has apparently a wider coverage, in dry weather, than the non-cutoff system. It is commonly used centrally at 90-100 ft. spacing, and 25 ft. mounting height. In these circumstances, with adequate power, a centrally mounted cutoff system will cover a double carriageway with outer kerbs over 60 ft. apart in suitable conditions, though the use on such wide streets needs confirmation. A non-cutoff system would give in such an installation such a bright region near the row of lanterns that the outer kerbs would be very inconspicuous by comparison. The cutoff system should, however, be used with caution when the road surface is smooth, for in wet weather the surface will tend to flood. When this happens the "head" of the patch is apt to collapse, and, since there is no (or very little) "tail," a very poor result may occur. The cutoff system needs more power than the non-cutoff for comparable brightness; the revealing power is inherently lower by comparison than in a well-designed non-cutoff system, and the requirement of short, regular spacing is an embarrassment in some situations. The cutoff system cannot be "tailored" to match the individual features of a road as a "non-cutoff" system can. Nevertheless, the cutoff system can give remarkable and very pleasing results, with adequate revealing power; and we shall doubtless see a

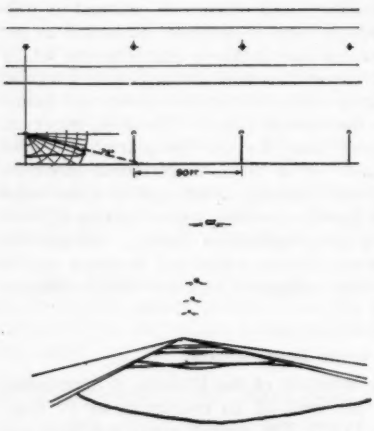


Fig. 12. Mechanism of cutoff lighting.

Fig. 13. Unidirectional non-cutoff lighting of arterial road.

development of cutoff lighting, or perhaps a compromise system with a little more flexibility and longer spacing than the full cutoff.

(10.4) Unidirectional System

For double-carriageway and one-way traffic routes with little pedestrian traffic, it is possible to exploit the properties of the road surface by sending light only in the opposite direction to the traffic. The full theory of this system has recently been explained elsewhere [27]; it results in a great saving of power for a given result, and a much increased revealing power; it prevents the formation of a constellation of bright lanterns which is likely to occur with double carriageways. The other carriageway appears dark and attention is diverted from it. (Fig. 13.) This system has so far been used with the non-cutoff type of distribution and arrangement, but it is applicable also to the cutoff system, and should then result in a very effective installation for double carriageway roads.

(10.5) Lighting of Junctions and Roundabouts

It is obviously important to reveal as clearly as possible the kerbs and road junctions. It has been found that if the kerbs are to be clearly shown, lanterns should not be much overhung and should not if possible be centrally mounted. The kerb is revealed by the riser being left unlighted; overhung or centrally mounted lanterns light the riser and diminish its conspicuousness. In addition, with non-cutoff distributions they result in a very bright region on the road surface being formed away from the kerbs, which diverts attention from them. This latter effect is reduced when cutoff distribution is used.

Experience has led to two recommendations for the siting of lanterns at junctions, applicable particularly to the non-cutoff system, by which they will be made most clearly visible. One of the most conspicuous features of a junction is the return of the kerb as it crosses the footpath; and it has been found that a lantern placed on the near side just beyond the junction is effective in revealing the return of the kerb

by leaving it unlighted and forming its shadow. A cross road has thus four lanterns sited beyond the junction on the near side of each arm. A lantern placed just before a junction, on the other hand, is effective in concealing it.

The second recommendation applies to situations such as a T junction, in which the driver in the side road has to be made aware of the cross road which he is approaching. Here a lantern may be placed opposite to the end of the side road and so sited as to lie right in the path of the driver, breaking the line of the lanterns in the side road and drawing attention to the presence of the cross road.

These two recommendations cannot often be both applied at once at a T junction, and one or other must be selected according to circumstances and to the siting of other nearby lanterns.

Roundabouts constitute a more difficult problem which has not yet been finally resolved. To some extent the method of lighting will depend upon the lighting in roads leading to the roundabout. Two principles have also emerged: one is the placing of lanterns on the central island in the path of the driver, like those in the second recommendation for T-junctions; another is the siting of lanterns on the outside of the roundabout so that they reveal clearly the apparent corners which the driver will have to negotiate while in the roundabout. Advantages have been found from the use of cut-off distribution for these latter lanterns, since the driver is never so far from them that he needs long bright tails to the patches which they form, and the use of a cut-off distribution reduces the glare and the confusion from many bright lanterns. For the lanterns on the central island facing the oncoming driver there has been found to be advantage in using unidirectional lanterns, of the kind used for one-way streets described in the previous paragraph. The distribution may be either cut-off or non-cut-off. This results both in a reduction of load and in the avoidance of a forest of lights on the island. An array of lanterns which is confusing and difficult to read is particularly undesirable, and the unidirectional lantern reduces this trouble considerably. Another method, useful when the approach roads are unlighted, is to use cut-off lanterns on the island; this avoids unnecessary glare, which would be severe in an otherwise unlighted road. Roundabouts are such important features of a road, and vary so widely in local conditions, that it is difficult to formulate a universally applicable scheme of lighting. Experiments are still in progress, and the most satisfactory scheme has still to be found.

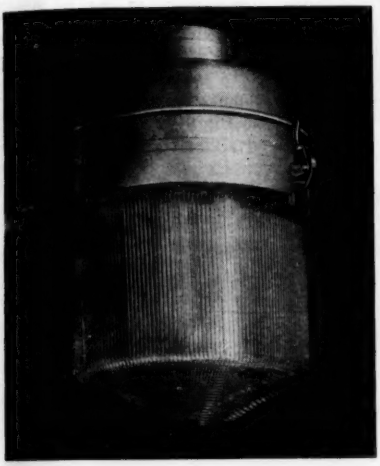
(10.6) Modern Lanterns

The lanterns designed for street lighting have undergone considerable improvement in the period under review. In 1927 nearly all lanterns were constructed in the tinsmith's shop, and were spun or built by hand from sheet steel or copper (Fig. 14). They were consequently not very robust or precise, and their light distribution was maintained by adjusting each lamp individually with a focusing arrangement. Nearly all lanterns were round, a form which is simple and cheap to manufacture, but suited only to lamps having a vertical axis of symmetry.

The coming of discharge lamps caused a great change in lantern design. Although the first H.P.M.V. lamps could be burned only vertically, the first lanterns made for them were of box form, which is expensive, and difficult to make watertight. (Fig. 2.) Later, the vertical burning lamp was provided with a circular bowl refractor, which gave a reasonable distribution, and there was a return to round lanterns. A revolution was brought about by the introduction of diecast metalwork and side-entry mounting. This made possible a simple, inexpensive lantern of great rigidity and accuracy, capable of withstanding heavy vibration and quite watertight. (Fig. 15.) The side-entry gave a better and simpler attachment to the bracket and increased the mounting height. This form of construction is also now used for lanterns for tungsten lamps, now made much more rigid and robust and with fixed focusing

(Right). Fig. 14. Old-fashioned lantern.

(Below). Fig. 15. Modern lantern for vertically burning H. P. M. V. lamp: non-cutoff distribution.



The most important development in lantern construction has been this use of aluminium alloy die-castings and engineering practice in place of sand-castings and spinnings or tinsmith's work.

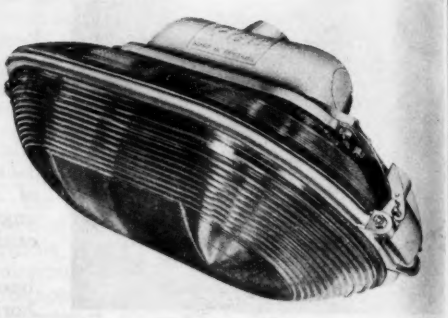
Before long it became possible to burn H.P.M.V. lamps with their axes horizontal, and lanterns were developed to take advantage of this orientation of the lamp. They necessarily departed from the round form and are more expensive, though they have a somewhat more suitable light distribution. Burning the lamp on its side requires a magnetic deflector to maintain the arc in the centre of the bulb, which adds to the cost; lamps can now be made which will give good lives without a deflector, but the contact of the arc stream with the wall of the bulb lowers the efficiency by some 10 per cent. Most lanterns for horizontal burning lamps are of box form, with two refractors; some use a single refractor trough of box form, which is an advantage, for it is usually cheaper to mould corners or their equivalent in glass than to form them in metal and have to make them watertight (Fig. 16). One is formed from two refractors in the form of an oyster, and is nearly all glass (Fig. 17).

Lanterns for sodium lamps are often open, with two refractor plates or two mirrors, or sometimes a combination of the two. Enclosed lanterns are also constructed. The sodium lamp with its low loading and consequently low temperature, permits the use of plastics; sodium lanterns have been made with a transparent plastic trough to which plastic refractors are cemented, and one lantern is almost entirely constructed of plastic material (Fig. 19). The advantages claimed for plastics are light weight, freedom from corrosion or weathering troubles, little maintenance, and simpler fixing; they can be drilled or fixed with adhesive. They are more expensive than the more conventional materials, and have come into use too recently to permit dogmatic opinions about their performance, but they have evidently come to stay.

The fluorescent lamp is the most recent comer to street lighting. The author was guilty of expressing the opinion that this lamp was not suitable for the purpose, because of its low light output, fragility and large size; he felt—as did many others—

(Left). Fig. 16. Modern lantern with one-piece glass "box." Horizontally burning H.P.M.V. lamp: semi-cutoff distribution.

(Below). Fig. 17. Modern lantern without corners. Horizontally burning H.P.M.V. lamp: non-cutoff distribution.



that the advantages of good colour and low brightness would not outweigh these disadvantages. But experience has proved otherwise. The novel appearance, good colour and low brightness are advantages for which some municipalities are prepared to pay, for important streets, although the capital cost of the lanterns and the cost of maintenance are high; and this country may congratulate itself on having been the first to succeed in using this lamp for street lighting, and to produce installations of very high quality unequalled anywhere in the world. The lanterns used are necessarily large, and would be really impracticable but for the use in their construction of aluminium alloys and plastics. At the time of writing nearly all lanterns use anodised aluminium trough reflectors, one for each lamp; lanterns have also been produced using plastic refractor plates instead of reflectors. Each lantern has usually three or four 80-watt lamps (Fig. 18); there are some two-lamp lanterns, or occasionally single 80-watt lanterns for special purposes, but multi-lamp lanterns are generally necessary to obtain sufficient flux. The lanterns are enclosed, and the heat from the lamps and auxiliaries is sufficient to maintain the temperature of the lamps at an efficient level in the weather conditions experienced in this country.

(11) Outstanding Problems

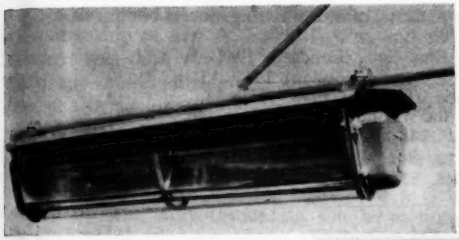
Probably the most important problem to be solved is the lighting of residential roads. The mileage of residential roads is about five times that of traffic routes; and the power and capital available to light them is totally inadequate for the requirements. So far we do not know how best to use what is available. The methods used hitherto have generally been small-scale imitations of traffic-route methods, and have achieved the worst of both worlds; there is room for some careful experiment and a new approach in this field.

We also know little about the best ways of lighting arterial roads; and it could doubtless be argued that the traffic that they carry does not justify lighting them over

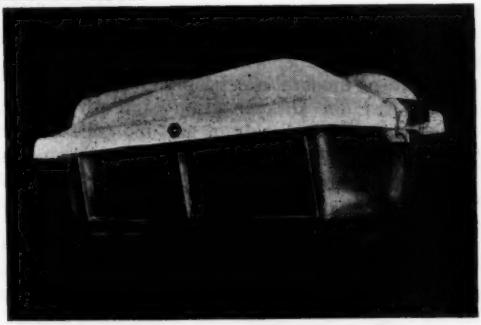
the whole of their length, or over long stretches. The by-pass roads in and near great cities do, however, undoubtedly call for lighting, of a kind that they seldom receive, and there are some problems unsolved here. The use of cutoff lighting and unidirectional lighting for double-carriageway roads are two contributions to the art which need further experiment and study.

We have in this country few roads of great width, and our lighting systems have grown up round our narrow and sinuous roads. But we have to compete in the export market for the lighting of wide straight thoroughfares, in which centrally sited lanterns cannot be used, and we need to develop further the special techniques which such roads demand; our conventional methods would not work. Much the same is true for roads with very large trees, and for bridges, which present peculiar problems.

The real, day-to-day problem of street lighting is however not the design of new lanterns or lighting systems, but the job of keeping tens of thousands of lanterns clean and in lighting every night of the year. We have not yet solved all the questions of maintenance, and particularly of control, though some cities have elaborate and ingenious systems in operation. We need simple lamps of high efficiency, high power, and good colour, the light of which is accurately controlled by lanterns which are very simple to maintain and which will not easily go wrong, and which can be switched on and off simply and reliably at will from a central control point with cheap apparatus. The lighting of our streets is by far the biggest job of exterior lighting, and is of great public importance; it is not solved yet.



(Above). Fig. 18. Fluorescent street lighting lantern for three 80-watt lamps.



(Right). Fig. 19. Street lighting lantern for sodium lamps, constructed mainly of plastic materials.

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R. Maxted. Trans. Illum. Eng. Soc. (London) 1944, **9,** p. 26.
F. C. Smith, Public Lighting, 1949, **14,** p. 200.
(26) J. M. Waldram, Trans. Illum. Eng. Soc. (London) 1938, **3,** p. 155.
(27) J. S. Smyth, Public Lighting, 1948, **13,** p. 100.

Discussion

MR. F. C. SMITH said he was happy and honoured to be invited to open the discussion on this paper as few men had made such an outstanding contribution to the technique of modern street lighting as the author.

He had not always agreed—and for that matter did not still agree—with the emphasis that Mr. Waldram and his collaborators had placed on certain aspects of the street lighting problem, but that in no way detracted from his admiration for the pioneer work that he and his co-workers continued to make available to all interested in public lighting. In paying this tribute he acknowledged freely that the work reported by the author over the years had been of value and assistance to the industry which he himself served.

In considering technical progress since the 1920's the author had called attention to many of the important signposts but he was rather inclined to think that the author might have joined the main road a little earlier and called attention to the technical requirements of some of the contracts placed for both gas and electrical installations prior to 1920, as these represented a complete breakaway from what was then the established practice of purchasing c.ft. of gas or units of electricity and which substituted, so far as he was aware for the first time, requirements for both candle power and distribution. He regarded these contracts as representing the new approach to the street lighting problem.

He had little to say in detail about the various milestones to which the author had referred. The paper, since it was a historical survey, covered well-known ground but it was, nevertheless, extremely valuable as it enabled one to see the progress made over the years.

The author stated that the first requirement on the Continent was not high road

brightness but low glare. If he wished to be provocative he might say how right our Continental friends were. Perhaps it would be fairer to say that we were prepared to accept more glare than was considered tolerable on the Continent and it was possible that the best of both systems might be obtained by choosing a distribution which might be termed, in the absence of a precise definition, "partial cut-off." His own opinion was that the glare experienced in many of our installations generally accepted as representative of good practice to-day, was excessive and a source of discomfort, embarrassment and fatigue to the driver. On many occasions when driving he had experienced a sense of relief when passing from an installation which was generally recognised as first-class into one considered by many to be less effective.

The author was right when he said that some modification of the cut-off system might be the lighting of the future. Speaking personally, he was less worried by a system which might produce somewhat patchy effects on the road but which was relatively free from glare, than by an installation which had fairly even road brightness but excessive glare. This remark, of course, must be qualified by saying that patchiness could only be tolerated provided the less bright patches were not sufficiently large, as seen by the driver, to prevent an object being revealed in silhouette.

The paper dealt at some length with the findings of the experimental panel under the chairmanship of Mr. A. E. N. Taylor, and stated that one of the most important conclusions was that revealing power was largely dependent upon factors which were variable and quite outside the control of the designer or anyone else. This, of course, was an accurate statement. One of the factors, however, which was variable —especially under changing weather conditions and the varying degrees of polish imparted by traffic, was the reflection properties of the road surface.

Without wishing to commit himself to a definite opinion at this stage, he had wondered of late, notwithstanding the large number of factors which contributed to the final result, whether certain distributions were less dependent than others on the changing character of the road surface and whether this might be especially true of the newer and rougher surfaces now commonly used. He was, of course, assuming that if this was the case, the installations using lanterns of differing distribution characteristics were sited and designed to suit the requirements of the particular distribution adopted.

He was interested in Mr. Waldram's opinion in regard to the relative merits of a code or specification and thought that the answer was by no means so clear cut as had been suggested. He himself dealt with this matter at last year's A. P. L. E. conference and he would, therefore, refrain from further comment except to say that he would not quite give the omnipotence to either the Report of the Departmental Committee of the Ministry of Transport or the Code of Practice which it appeared the author gave when he said: "The only sound way of appraising the merits of a design is to compare it. . . ." This remark must not be construed as a criticism of the code about to be issued for comment, as he had reason to believe that the Code of Practice, when it appeared, would be a sound document and would be extremely useful. In the last portion of his paper the author rightly included some illustrations of modern electric lanterns and had spoken of the importance of the development of new light sources with which they were all now familiar.

The gas industry had no new method of light production to report at present but the period which the author had reviewed had been one of steady and effective progress in the development of street lighting equipment. The physics of the Bunsen burner had been and was continually under study and had resulted in improved burner design etc. Maintenance facilities had also received special attention, and

up to 70 per cent. of the rated output could be maintained economically throughout the life of the lantern.

(Some lantern slides were then shown illustrating modern gas lighting units).

Finally, Mr. Smith said he agreed with the author that there was some important work to be done to produce an effective Code for Class B lighting which, in his view, was somewhat overdue.

DR. J. W. T. WALSH said it was a matter of common knowledge that the B.S.I. with the Institution of Electrical Engineers, had in preparation a Code of Practice for street lighting and probably most people interested knew that that Code of Practice would be going out for comment in a few weeks' time. When he mentioned that Mr. Waldram was one of the members of the Panel which had been responsible for drafting that Code, it would readily be understood that any merits it might have were in no small degree due to Mr. Waldram's collaboration with the other members of the Panel.

Apart from that, he would like to refer to the concluding paragraph of the paper, entitled "Outstanding Problems." The Code of Practice to which he had referred was confined entirely to traffic routes, but there were, of course, other problems which no less demanded attention. The mileage of residential roads were several times the mileage of traffic routes in this country and therefore the Code of Practice Committee was proceeding at once—without waiting for the completion of that part of the Code dealing with traffic routes—to take up the matter of the other roads in a second part of the Code. It would generally be agreed that the lighting of residential roads required an approach from a rather different point of view from that of traffic routes. He felt confident that there were a number of highly successful installations in residential roads in this country but, unfortunately, the number of unsuccessful ones was very much greater and a good deal of searching would have to be done to find the successful installations from which the Committee might learn something when they came to consider this part of their Code. Therefore he appealed to any member of the Society to let the Committee know of any installations in Class B roads which they thought possessed particular merit. It would be extremely helpful to have any information of that kind.

Later on, perhaps, the Committee would tackle some of the other problems mentioned by Mr. Waldram such as the lighting of roundabouts, and one which had not been mentioned, viz., the lighting of vehicular tunnels which was very important although it was a problem which did not arise very often in this country. He had been reading with interest the recently issued French Code of Practice for street lighting and it gave a good deal of attention to the lighting of vehicular tunnels. These would probably increase in number in this country and it was necessary to think of how they were to be lighted in the most effective way.

MR. N. BOYDELL called attention to the different treatment needed for main traffic routes and shopping streets. On traffic routes, where pedestrians are comparatively few, colour distortion did not matter; but in shopping streets where pedestrian traffic is high, it did matter.

The author tended to dismiss Sodium lightly in a sentence or two, but in his view Sodium with non cut-off fittings was entirely satisfactory at present as far as traffic route lighting is concerned. In shopping streets, however, he had arranged a combination of mercury and tungsten lamps in a totally enclosed symmetrical lantern which gave the effect and colour of very bright moonlight.

As to road surfaces, a great deal had been heard about the lack of co-operation between road engineers and lighting engineers and there seemed to be a sort of per-

petual friendly no-man's land. Was it not possible to get together definitely and deliberately and have a joint meeting to discuss this problem?

Referring to the different types of fittings described by the author Mr. Boydell said that he was finding that sodium lamps in totally enclosed lanterns seemed to have 50 per cent. more life than those in open fittings.

As regards fluorescent lanterns, the author stated that the novel appearance, good colour and low brightness were advantages for which municipalities were prepared to pay but Mr. Boydell strongly disagreed with that so far as the first point was concerned. The appearance of the fluorescent lantern might be novel but it was not pretty. Indeed, he regarded it as extremely ugly; and municipalities certainly will not use it from the point of view of appearance. In this he was speaking of the appearance of the fittings in daylight, and he felt that the aesthetic exactitude displayed with regard to floodlighting appeared to be non-existent where the daylight appearance of a fluorescent street lighting installation was concerned. He felt that for shopping streets the immediate future lay in the development of the 2 ft. fluorescent tube. He knew that the scientific experts would say that there were technical difficulties but the possibilities of applying fittings housing 2 ft. tubes to street lighting should be investigated to the full as that might be the solution eventually to the problem of lighting really satisfactorily both motor roads and shopping streets and also getting an acceptable appearance by day. Thus, at least, they would avoid the hangman's paradise which had begun to make its appearance.

MR. GRENFELL BAINES referred to street lighting as part of the broader pattern of town spaces. As a town planner and architect he would like to see closer co-operation between designers in all spheres; for this reason he would like to think that those concerned with appearance would be invited to the proposed "party."

He would like to see many fewer lighting units, and that was a problem for the lighting engineers to solve; he wondered how much the daytime visual effect of present schemes was controlled entirely by the limitations of the fittings.

As to the implication that brighter road surfaces helped lighting schemes, he had heard the suggestion by another public lighting engineer that the brightness of snow-covered roads would be ideal: it might from the point of view of lighting only, but considering general appearance nothing could be worse either for aesthetics or comfort; under such conditions we should all soon be suffering from glare effects.

It was significant that such a detailed history of street lighting should contain no reference to aesthetics, particularly when the author was, as Mr. Baines knew, very conscious of their importance. The truth, that up to now aesthetic considerations had been almost completely overwhelmed by technical and economic needs, need not be emphasised by Mr. Baines; our streets were doing that very well at this moment!

He referred to the changing shapes of town pattern, particularly in new residential areas where relatively tighter knit development alternated with larger scale open greens and where road network design resulted in greater concentration of through traffic on certain roads; others being immediate approaches to houses only and not subject to use by fast moving vehicles.

Thus from the linear shapes of street spaces we were moving to square and round spaces which suggested a new approach with new problems.

His solution for a new town in the north had been fewer higher mounted fittings —35 to 40 feet. The admitted basis of design was aesthetic, day and night appearance being considered together; the former from the point of view of minimum and controlled interference with spatial effect, in harmony with the three dimensional characteristics of the design; the latter from effectively lighting the open spaces which as Mr. J. F. Colquhoun pointed out would have been large pools of darkness if any

recognised low mounted scheme following the lines of the perimeter roads had been used.

Mr. Colquhoun, to whose work Mr. Baines would like to pay tribute, had been very polite when asked to comment on the first experiment, and Mr. Baines was in no doubt that closer collaboration was the only effective way towards perfecting lighting design in all its aspects. He would like to help in bridging the gap between architects and road and lighting engineers, which, as he saw it, meant the former understanding more of the fundamentals of the science of lighting while putting over to the engineers an understandable explanation of their art.

MR. J. A. WHITTAKER referred to the success of the first system mentioned using the high-angle beam and suggested that it might be possible to achieve a further limitation of glare in that system by the use of larger and consequently more expensive lanterns, or, alternatively, by the use of pairs of lower-power lanterns mounted in tandem.

MR. J. M. WALDRAM, replying to the discussion, agreed with Mr. Whittaker that there were some advantages in reduced glare if the size of lanterns were increased; but the gain was not dramatic. The facts were known, and it was possible to estimate the results in advance; the fluorescent lanterns gave an indication of the advantage to be gained. To obtain a significant reduction in glare required a very large lantern, and it would then be necessary to meet Mr. Grenfell Baines's and Mr. Boydell's just criticisms.

He agreed with Mr. Grenfell Baines on the importance of aesthetics, and it was true that that aspect has not been dealt with in the paper because insufficient work had been done upon it. Nevertheless, the lighting of streets was primarily a technical problem to which the aesthetics had to give way; it would be wrong to spend public money upon systems which did not work well because it was a first requirement that they should look well. He welcomed Mr. Grenfell Baines's reference to the coming of new patterns of town planning. Illuminating engineers would doubtless soon be faced with new problems, particularly in residential areas, and in these the aesthetic considerations would be more important than they had been. He did not think, however, that lighting problems would be solved until the man of aesthetics and the man of engineering coexisted in one person.

The combination of mercury vapour and tungsten filament lamps for shopping streets, referred to by Mr. Boydell, had been used in a number of installations, and had given good results. Mr. Boydell had used the term "traffic route" in the sense in which the term "arterial road" had been used in the paper, to mean a road carrying much vehicular and little pedestrian traffic. In the M.O.T. report, "traffic route" was defined as a road (among other things) "carrying appreciable pedestrian traffic," and would include the shopping streets to which Mr. Boydell referred. He agreed that the non-cut-off system using sodium lamps was effective in arterial roads carrying little pedestrian traffic.

The increase of life of sodium lamps in enclosed lanterns, reported by Mr. Boydell, was new to him and was a point which it would be interesting to have confirmed by a controlled life test. He understood that the Road Research Board was interested in the study of the optical properties of road surfaces, and he looked forward to some co-operation such as that suggested by Mr. Boydell.

The B.S. Code of Practice, referred to by Dr. Walsh, was very late in making its appearance. He thanked Dr. Walsh for attributing to him some of the credit of the code, but he wondered whether he ought rather to bear some of the blame for its

delay! The lighting of roundabouts and of tunnels were interesting problems to which he hoped more attention would be given.

He had worked together with Mr. F. C. Smith for many years, and he always listened with interest to his discussions of the subject. He appreciated his references to the work of his colleagues and himself. If he had not given adequate reference to the Westminster contracts, it was because they had been instituted before his time; he had referred to them in presenting the paper. Mr. Smith had commented at some length on glare; in writing the paper he had set out to be an historian rather than a commentator, and so had confined himself to a record of progress. In the early days in this country we had been keen to avoid glare; later, improved road brightness had come to the fore. It might be that the pendulum was now swinging back again. Nevertheless, it was essential not to pursue comfort at the expense of safety; and he felt that there was some danger of doing so. Patchiness was very difficult to define or assess. He agreed that some kinds of patchiness did not matter; but a pattern of brightness which conflicted with the pattern of the geometry of the road resulted in confusion and danger, and was to be avoided.

Mr. Smith had enquired whether some systems were less dependent than others upon the properties of the road surface. The non-cut-off and the cut-off systems were both sensitive to change in properties, but the requirements for the two systems were somewhat opposed; a surface good for one system tended to be poor for the other. He would expect the system least sensitive to change in road surface properties to be the semi-cut-off (medium angle beam) system with opposite arrangement.

Mr. Smith had said that he could not consider the M.O.T. report as omnipotent. Perhaps he had meant "omniscient" rather than "omnipotent." The report was an excellent document based upon sound evidence, but he agreed that it was not omniscient; it was for those concerned to see to it that in a developing subject no one pronouncement became omnipotent.

Additions to List of Members

The following applicants have been duly elected by the Council to membership in the Society, and their names have been added to the list of members.

CORPORATE MEMBERS:—

Brown, A. F. ..... 3, Blanchman's Road, Warlingham, SURREY.
Colvin, D. R. ..... 4, Winburne Crescent, Hamilton, LANARKS.
John, A. G. ..... 18, Harle Street, Neath, GLAM.
Sayce, H. ..... 17a, Sherbourne Terrace, Clarendon Street, Leamington Spa, WARWICKS.
Turner, H. J. ..... Stage Electrical Equipment, Ltd., Offley Road, The Oval, S.W.9.

TRANSFERRED TO CORPORATE MEMBERSHIP:—

Callaway, J. D. ..... 27, Dalton Road, Aberavon, GLAM.
Prothero, G. J. ..... 1, Leigh Road, Pontnewynydd, Pontypool, MON.
Watts, P. L. ..... "Granville," Highfield Road, Westerhope, NEWCASTLE-ON-TYNE.

Register of Lighting Engineers

The Council have accepted the following applications for inclusion on the Register of Lighting Engineers:—

L. G. Applebee, W. E. J. Drake, R. I. Duff, S. R. Hook, C. K. Ross, A. J. Singlehurst, K. Oldham Smith, H. E. G. Watts, R. G. Williams.

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